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Catalog of Absolutely Calibrated, Range Normalized, Wideband, Electric Field Waveforms from Located Lightning Flashes in Florida: July 24 and August 14, 1985 Data

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The electric field and its time derivative from located intra-cloud and cloud to ground lightning discharges were measured in Florida over salt water paths with flat plate antennas mounted on the roof of a metallic trailer. Also recorded was the HF energy spectral density within a 1.45 μsec time window at either 5, 10, or 15 MHz averaged over a 1 MHz bandwidth. In this report we present range-normalized waveforms of all located lightning events in two storms occurring on 07/24/85 and 08/14/85. These events are classified into 15 categories according to previously identified electric field waveforms. Statistical and spectral analyses of these data will be presented in forthcoming papers. One result became evident from the data. Approximately 57% of the first return strokes had HF radiation preceding them indicative of the characteristic pulses described by Beasley et al. [1982]. It was unclear if this result indicates that characteristic pulses do not always precede first return strokes.

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CONTENTS

CATALOG OF ABSOLUTELY CALIBRATED, RANGE NORMALIZED, WIDEBAND, ELECTRIC FIELD WAVEFORM FROM LOCATED LIGHTNING FLASHES IN FLORIDA: JULY 24 AND AUGUST 14, 1985 DATA

I. Introduction

Understanding the electromagnetic signals produced by lightning is important both scientifically, to learn about the physics of the discharge, and practically, to define the electromagnetic hazard. The broad-band (i.e., time-domain) electric and/or magnetic field impulses tend to have characteristic and reproducible waveforms that can be used to identify different processes within the complex phenomenology of a cloud-to-ground (CG) or intra-cloud (IC) lightning flash (e.g.; Kitagawa and Brook, 1960; Lin et al., 1979; Weidman and Krider, 1978, 1979). The identification of these processes is invariably inexact, however, due to borderline cases and processes whose physical characteristics are unknown. Therefore, a compilation of many examples of each type of process is useful in developing a more consistent classification. This compilation should also lead to a better understanding of the composition of both CG and IC flashes.

Field experiments were conducted at Kennedy Space Center (KSC), Florida, during the summers of 1984, 1985, and 1987 to obtain calibrated, wideband, radiation field waveforms and spectra of impulsive events within the lightning flash. These events include first return strokes and various types of leaders, subsequent return strokes, and cloud pulses. The 1984

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experiment used relatively simple equipment and has been described in detail by Leteinturier et al. [1985]. They discussed the statistics of the peak electric field and its derivative, the energy spectral density (ESD), and the implied mean peak current derivative of various events within one Florida thunderstorm. A more complex, fully digital data-acquisition system was used to record vertical electric fields at ground level from lightning during the summers of 1985 and 1987. Bailey et al. [1988] have discussed the statistics and spectra for some of the 1985 data. The 1987 data will be analyzed in future reports.

In this report we present a collection of 15 different classes of CG and IC lightning events for the days July 24 and August 14, 1985. The event type is identified by the general characteristics of each waveform. Future reports, for additional storms, may be expanded to include additional classes as the analysis progresses. All lightning waveforms given herein except the "slow E" (see sect. III) have been range normalized to 100 Km (1/R dependence), which facilitates comparison of the radiation fields among different flashes. A simple procedure based on HF radiation is used to test whether "characteristic pulses" (defined later) precede all first return strokes as suggested by Beasley et al. [1982].

II. Instrumentation

A block diagram of the 1985 apparatus is shown in Fig. 1. This system was designed to record an entire lightning flash with moderate time resolution, while also capturing several of the impulsive events within that flash with much higher resolution. High resolution data were obtained from a group of digitizers sampling the "fast electric field" (fast E) and HF

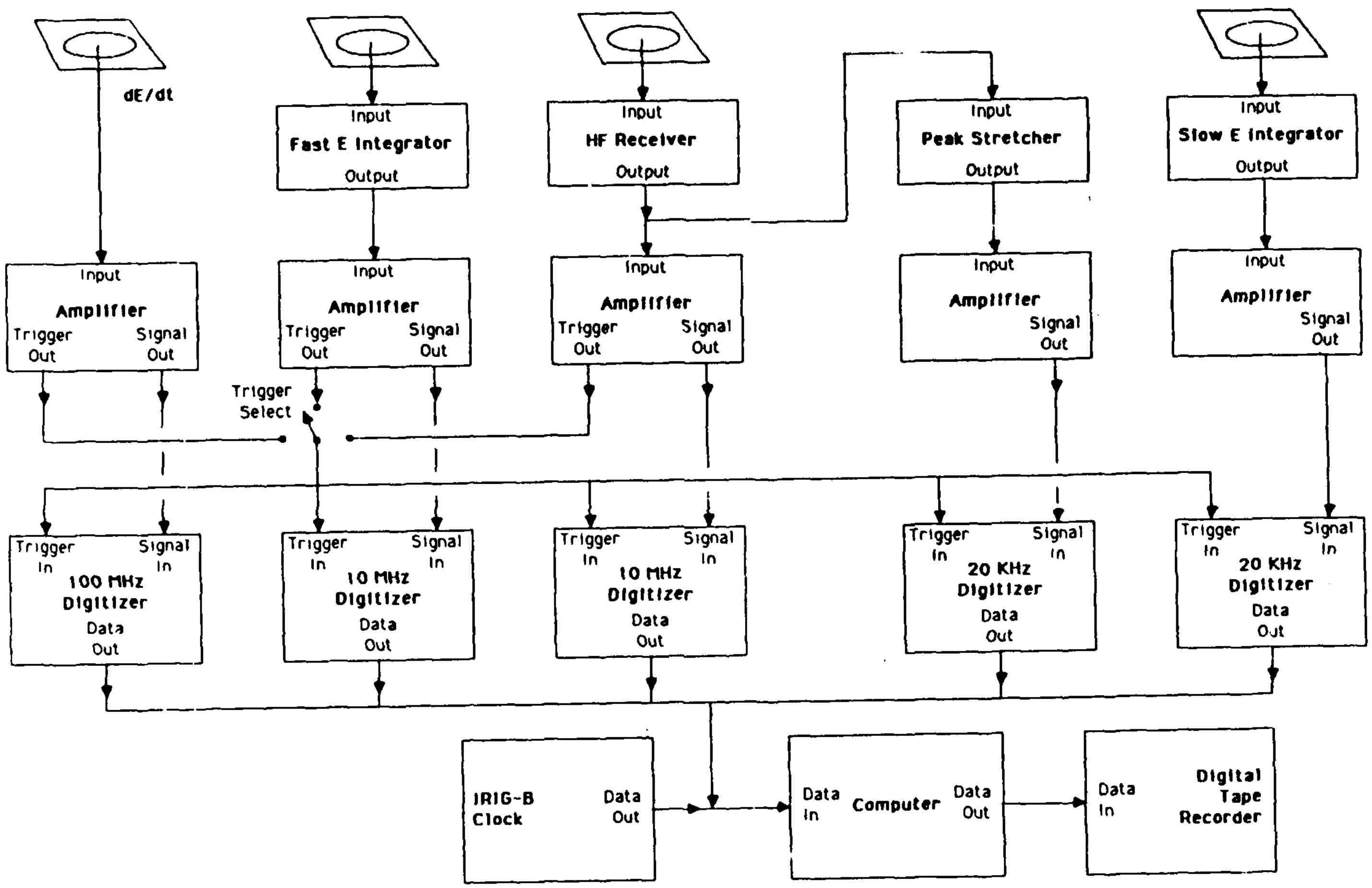

FIG. 1 -- Block diagram of the electric field recording system used in 1985. The trigger selector was set to the output of the HF receiver for the data reported here. In 1987 a second 100 MHz digitizer recorded the dE/dt signal in parallel but at a different gain to give better dynamic range. The digital tape recorder was also replaced with a second computer to display the data in real time and record it to replaceable 20 MB disk cartridges.

ESD (fast HF) at 10^7 samples per second and the time derivative of electric field (dE/dt) at 10^8 samples per second. The E antenna system had a 10 to 90% risetime of about 160 ns and a decay time constant of 1 ms. The HF receiver measured, as a function of time, the ESD within a time window of effective width 1.45 μsec, averaged over a 1 MHz bandwidth about the center frequency. The dE/dt antenna was similar to that described by Weidman and Krider [1980] and had a bandwidth of better than 30 MHz. For the data reported here, the system was triggered by the output of the HF receiver, which could be tuned to any center frequency between 3 and 18 MHz. The data from these high resolution digitizers were read into a computer memory and the digitizers re-armed in about 100 ms. Up to seven such bursts of high resolution data, each time-stamped to an accuracy of ±2 ms, could be recorded during a single lightning flash. The duration of the "flash" was defined by two slow digitizers that sampled the "slow electric field" (slow E) and the peak HF ESD (slow HF) at 2 X 10^4 samples per second for a period of 1.075 s starting 403 ms before the first trigger. The slow E antenna had a time constant of 10 s.

In 1987 the recording system was improved by reducing the dead time between high resolution events to 13 ms and by increasing the maximum number of bursts to 24. A second 100 MHz digitizer recorded the dE/dt signal in parallel but at a different gain to give better dynamic range. The slow sampling rate was also increased to 5 X 10^4 samples per second, and the duration of a "flash" raised to 1.31 s, without changing the basic configuration of the system.

Four 0.2 m^2 flat plate antennas were centered on the roof of a 5.5 m X 2.4 m X 2.4 m grounded metal trailer. In 1985, the trailer was connected

to a single ground rod with a DC ground resistance of 0.25 Ω. In 1987 six rods grounded the trailer, one at each corner and one in the center of each long side. The DC ground resistance of each rod was less than half an ohm.

During both 1985 and 1987, the instrumentation trailer was located just behind a row of low dunes on the ocean beach near KSC camera site 10. A photograph of the site is given in Fig. 2. The trailer was only 44 meters from mean high water, so that the propagation path for signals from lightning over the Atlantic Ocean was almost entirely over salt water.

The field enhancement factor for the antennas on the roof was determined to be 2.25 (1985) and 2.15 (1987) by comparing their signals with those of an identical antenna on flat ground nearby. This comparison was accomplished at night, using waveforms with little spectral power above 50 KHz, produced by distant return strokes, because the enhancement factor was found to be independent of the azimuth of incidence at these frequencies. Angular anomalies observed at higher frequencies are believed to be due to coupling into the long cable between the ground antenna and the electronics inside the trailer. The overall absolute accuracy of the peak electric field measurements is estimated to be ± 6%.

A comparison of dE/dt spectra from the roof antennas with those from a similar antenna on flat ground, connected to the trailer by fiber optics, (Bailey and Willett, 1987) showed no serious resonances in the HF band for the 1987 configuration. The composite return-stroke spectra in 1985 and 1987 were very similar, which suggests that the previous grounding configuration did not produce resonances or contaminate the 1985 data either.

Lightning locations were obtained from a three-station network of gated magnetic, direction-finders (manufactured by Lightning Location and

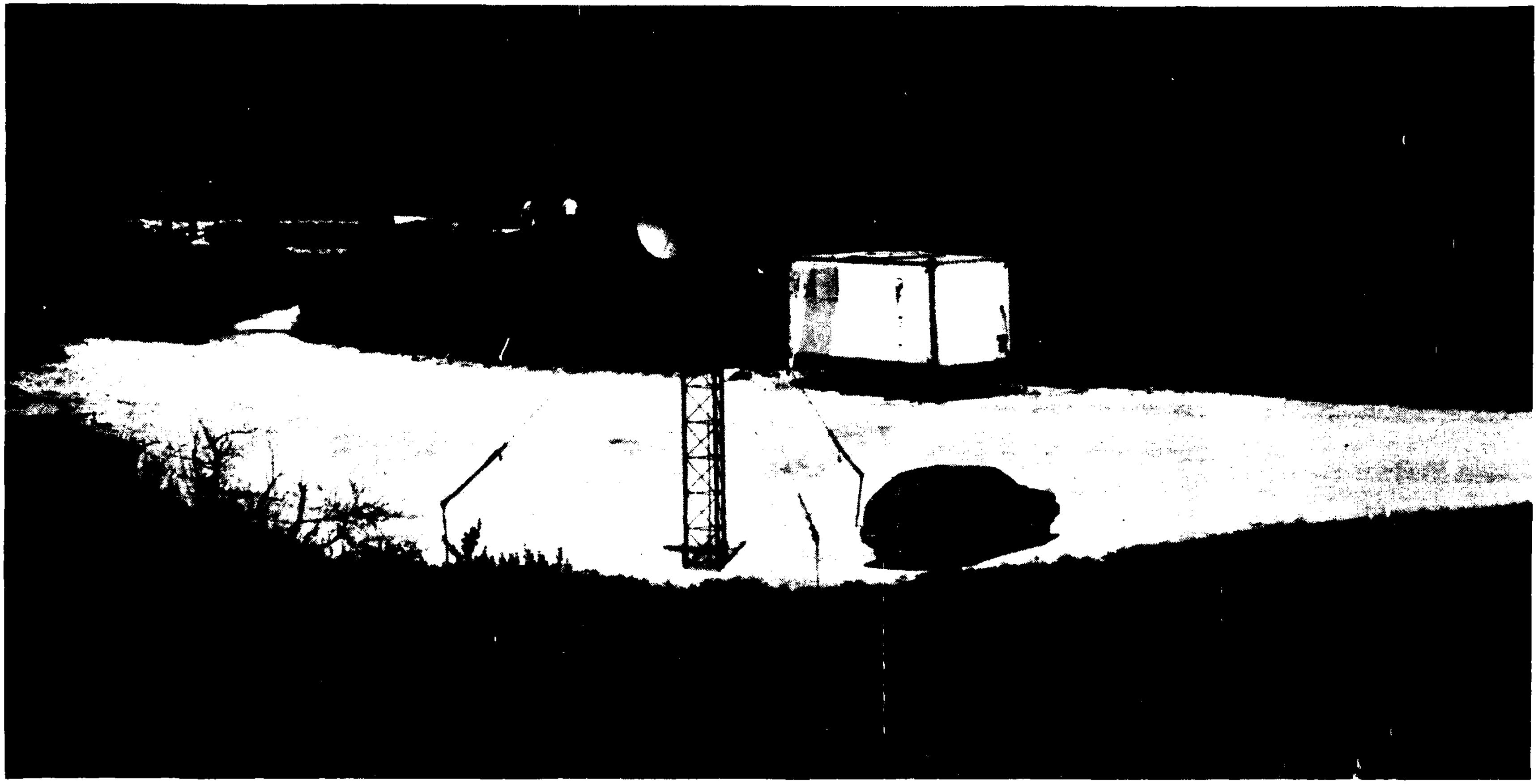

FIG. 2 -- Photograph showing the location of the trailer on the beach of the Atlantic Ocean for the 1987 experiment. A microwave transmitting tower is in the foreground. The 1985 location was nearly identical except that the microwave tower was absent. The view is approximately ENE.

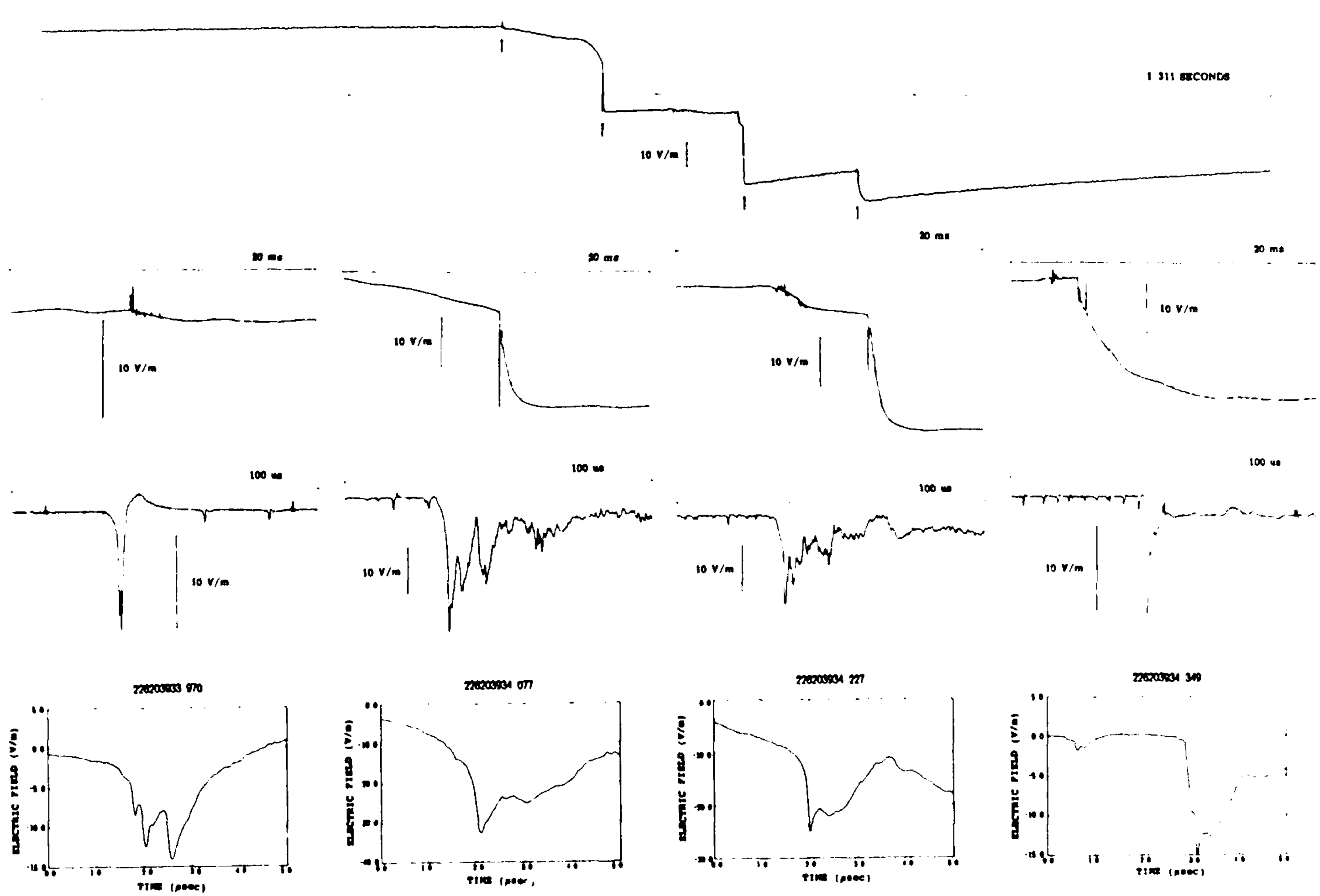

FIG. 3 -- Electric field change data for a CG flash occurring at 20:39:34 on August 14, 1987. The top waveform is the slow E record for a duration of 1.31 s. The second through fourth sets of waveforms correspond to slow E, fast E, and integrated dE/dt, respectively. They are expanded electric field signatures of the events indicated by the arrows in the first row on time scales of 20 ms, 100 µsec, and 5 µsec, respectively. This flash has not been range normalized.

Protection, Inc., Tucson, Arizona - Binford et al., 1983) that was operated for KSC by the Cape Canaveral Air Force station. This system was designed to locate only the ground-strike points of the first return strokes in normal CG flashes, i.e., those transferring negative charge to earth. For this study the raw data from the individual direction finders were re-analyzed with the application of appropriate site-error corrections (Krider, personal communication).

III. DATA AND PLOT FORMAT

Comparison of the radiation field magnitudes from lightning discharges requires knowledge of the discharge location. This requirement limits the data to either CG flashes or IC flashes occurring in a localized storm so that the range can be estimated. Therefore most of the data in this report is collected from CG flashes.

The CG flash (Uman, 1987, pp. 10-17) usually includes preliminary variations ending with a sequence of "characteristic cloud pulses" (Beasley et al., 1982) followed by a "stepped leader" and "first return stroke". "Subsequent return strokes" of several types may then follow. For example, the CG flash (Fig. 3) recorded at 20:39:34 on August 14, 1987, contains a characteristic pulse followed by two stepped leader and first return stroke pairs. They are followed by a subsequent return stroke preceded by a "dart-stepped leader". Preceding the initial first return stroke in the slow E record is a good example of the electrostatic field change due to transfer of charge by the relatively slowly ($\simeq 2 \times 10^5$ m/s) propagating stepped leader. Subsequent return strokes exhibit much briefer leader field changes because the propagation speeds of both dart ($\simeq 3 \times 10^6$ m/s)

and dart-stepped ($\simeq$ 1 - 2 X 10^6 m/s, V.P. Idone, personal communication) leaders are faster.

Multiple stroke flashes have more than one channel to ground approximately 44 % of the time (Thompson et al., 1984 - Fig. 2) suggesting that more than one first return stroke, as identified by the radiated field waveform, can occur within a single flash. Therefore, location of one stroke within a flash does not necessarily imply that all the other events have the same location. In order to obtain the most precise locations possible for range-normalization, we rejected events which might have occurred in channels to ground different from the one located by the direction finding system.

A stroke was considered located primarily by time coincidence with the magnetic-direction finders to an accuracy of approximately ± 5 ms. Other events in the flash were taken to have the same location as this stroke unless there was evidence that another first return stroke occurred in the flash. This criterion most often limited the number of located first return strokes in a flash to one. It also frequently forced us to throw out subsequent strokes and other events in flashes containing more than one first stroke. One case (see flash at time 17:31:04.283 on 08/14/85) with more than one first return stroke has been included, however. For this case, all three direction finders counted 11 or 12 strokes in the flash (within the 2.5° azimuth window for subsequent strokes). Because the slow E field change exhibited at least 11 steps, the ranges of two first return strokes within this flash were deemed known to sufficient accuracy.

Data were collected from two storms over the Atlantic Ocean, which occurred on July 24 (Fig. 4) north of the trailer and August 14, 1985

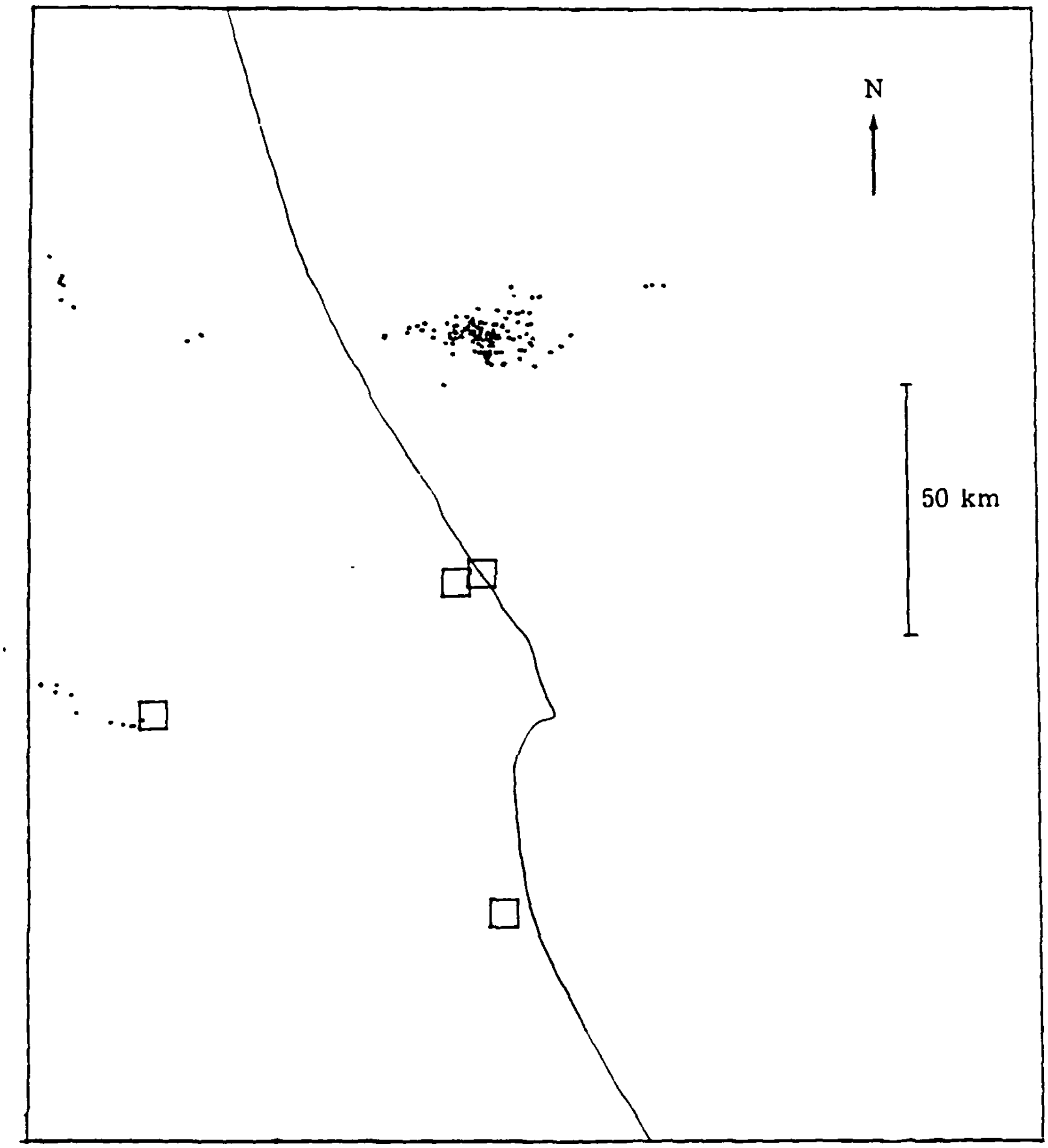

FIG. 4 -- Map showing the ground-strike points of CG flashes located by the magnetic direction-finding network during the period 20:25 - 21:00 UT on 7/24/85. The north-eastern-most square represents the location of our instrumentation trailer on the east coast of the Florida peninsula, and the other squares represent the three direction finders in the network.

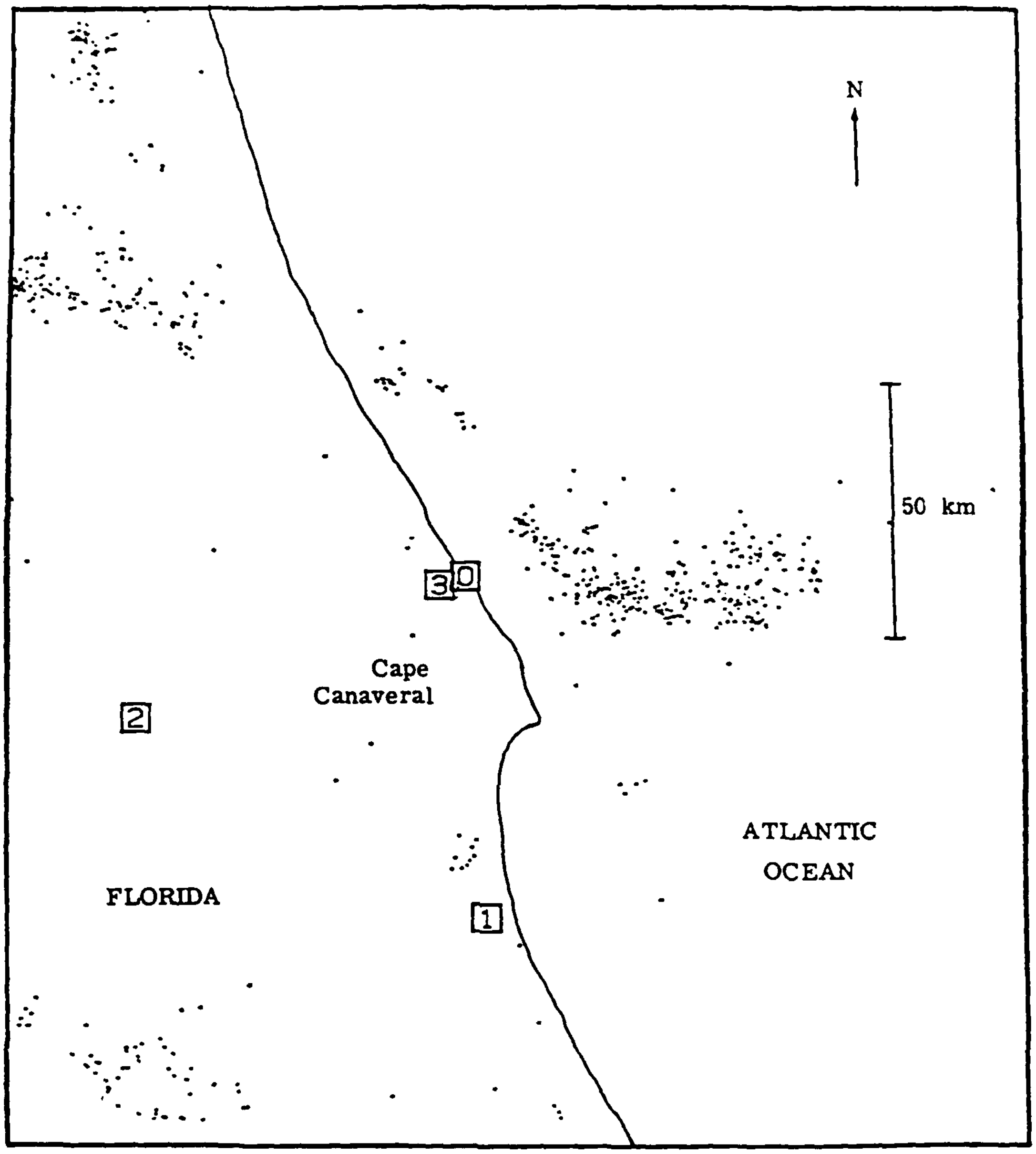

FIG. 5 -- Map showing the ground-strike points of CG flashes located by the magnetic direction-finding network during the period 17:22 - 18:42 UT on 8/14/85. The squares have the same representation as in FIG. 4.

(Fig.5) east of the trailer. These storms produced lightning at ranges from 40 to 60 km and 15 to 50 km, respectively. The ground-strike locations, discussed elsewhere for the 7/24/85 storm by Krider [1988], are believed to be accurate to ± 3 km or better. The propagation path for signals from both storms was almost entirely over the ocean, largely eliminating the severe high frequency attenuation that can occur because of signal propagation over poorly conducting land (Wait and Walters, 1963).

The HF receiver frequencies and the trigger thresholds, in $(V/m/Hz)^2$ at the trailer location, for both data sets are given in Table 1. Each table entry is correct up till the time of the next entry. The thresholds must be range normalized to 100 Km by multiplying by $(Range/100)^2$ for comparison with the data plots.

Table 1 -- HF center frequencies and trigger thresholds

Date	Time	Freq. (MHz)	Trigger Level $(V/m/Hz)^2$
07/24/85	20:06:00	5	$1.87*10^{-14}$
	20:26:00	10	$4.68*10^{-15}$
	20:27:15	10	$7.42*10^{-16}$
	20:47:00	15	$3.30*10^{-16}$
	20:47:15	15	$6.58*10^{-17}$
08/14/85	17:20:50	5	$5.92*10^{-14}$
	18:20:00	5	$2.97*10^{-14}$

The plots to follow are identified by event times rather than figure numbers. Every flash is plotted using identical formats. High resolution data for each located trigger event within a flash is represented by a "fast page" containing four plots. There is one "slow page" per flash containing two plots per page. More specific descriptions of the fast and slow pages are discussed below. The magnitude of the linear vertical scales among plots can vary and is chosen to give the best display of the

data. When digitizers are saturated, the saturation levels are indicated on the plots by dashed lines. The sign convention is that of conventional physics: a positive electric field at the ground is produced by deposition of negative charge overhead. A normal return stroke that lowers negative charge thus produces a negative field change. This sign convention is opposite to that used in much of the published literature.

Each fast page has the following format. On the left side, the fast E (V/m) waveform is plotted above the fast HF $(V/m/Hz)^2$ waveform, both at a resolution of 100 ns per sample for a total time of .4096 msec. On the right side, the portion of the fast E waveform coincident with dE/dt is expanded and centered above the dE/dt (V/m/μsec) waveform which is sampled at 10 ns for a total time of 40.96 μsec. The fast page title contains a date/time group followed by the event definition and range in Km (in parentheses). The date/time group is the time of the trigger. For example, the date/time group 226181216.300 can be decoded as day 226, hour 18, minute 12, and second 16.300. Universal time (UT) is used throughout. Subtract four hours to convert to Florida daylight savings time.

The fast pages for a given flash are followed by a slow page showing the context of each event within the entire flash. The slow E (V/m) waveform is plotted above the slow HF $(V/m/Hz)^2$ waveform, both at a resolution of 50 μsec per sample for a total time of 1.075 sec. The trigger times for the fast events are indicated by tick marks beneath the slow HF record. The slow title contains the start time of the record followed by the date and the range (in parentheses). During the July 24 storm, 60 Hz pickup dominates the slow E signal. This is caused by the increased gain needed for the low signal levels from the relatively distant lightning discharges.

Because of the nature of the fast and slow E integrators, there is no absolute electric field zero. For this reason, and to remove any electronic zero drifts from the data, zeros were computed numerically from each record. The fast and slow HF zero levels were set to the minimum value of the respective HF record. The slow E zero is equated to the average of the maximum and minimum values. The other two zero levels were determined by dividing the full records into four quadrants of identical length. The fast E zero level was equated to the average of the first quadrant whereas the dE/dt zero level was taken as the average of the first and fourth quadrants.

Assuming that the waveforms are primarily radiation field and hence retain their fundamental shape as a function of distance, all plots except the slow electric field (mostly electrostatic) have been range normalized to 100 Km. For some of the closest flashes, this assumption may be invalid. The original data can be reconstructed by multiplying the fast E and dE/dt waveforms by 100/Range, multiplying fast and slow HF by $(100/\text{Range})^2$, and leaving the slow E alone.

IV. DEFINITION OF EVENT TYPES

A. General definitions

The content of the data analyzed so far has required the definition of several categories of return strokes, leaders, and cloud pulses. Future reports may add other definitions. Most of categories are based on observations of earlier investigators. The 15 categories, with the abbreviations used in the plots in parenthesis, are as follows:

First return strokes (1st RS)
Dart-stepped subsequent return strokes (DS subs RS)
Normal subsequent return strokes (Norm subs RS)
Chaotic subsequent return strokes (Chaotic subs RS)
Anomalous #1 return strokes (Anomalous #1 RS) - jagged then smooth
Anomalous #2 return strokes (Anomalous #2 RS) - smooth then jagged
Multiple ground return strokes (Multiple gnd RS)

Stepped leaders (Stepped leader)
Dart-stepped leaders (DS leader)
Dart leaders (Dart leader)
Chaotic leaders (Chaotic leader)

Characteristic cloud pulses (Char cloud pulse)
Narrow positive bipolar pulses (NPBP)
Narrow negative bipolar pulses (NNBP)
Unknown cloud pulses (Unknown cloud)

Examples of most of the return stroke and leader events can be found in either Weidman and Krider [1978] or Weidman [1982]. These authors have defined first, dart-stepped subsequent, normal subsequent, and chaotic subsequent return strokes. (To be precise, subsequent strokes are preceded by either a dart-stepped, dart, or chaotic leader. In this report, subsequent return strokes are named for the type of leader preceding them.) A particular event is defined as a return stroke if the signature of the fast-rising portion of the return stroke waveform is visible in the 41 μsec dE/dt time window. If only the leader's signature is visible in the dE/dt window, then the event is classified as a leader. In addition to those identified by Weidman and Krider [1978] or Weidman [1982], three other types of return strokes - called anomalous #1, anomalous #2, and multiple ground return strokes - have been defined as described below.

Wideband recording systems have identified several types of radiation fields associated with cloud processes. Uman [1987 - sect. 4.3 and 13.6] has a good summary of these events. They include trains of unipolar pulses (Krider et al., 1975), bipolar pulses with structure on the rise to peak

(Weidman and Krider, 1979 and Beasley et al., 1982), and bipolar pulses with smooth rise to peak (Le Vine, 1980; Cooray and Lundquist, 1985; and Willett et al., 1989). So far, located trains of unipolar pulses have not occurred in our data. Bipolar pulses with structure on the rise to peak, if they have negative initial polarity and precede first return strokes, are called characteristic pulses. Bipolar pulses with smooth rise to peak are called NPBP's if they have initial positive polarity and NNBP's if they have initial negative polarity, as long as they are sufficiently narrow and have the characteristic dE/dt signature defined by Willett et al. [1989]. Our last category, unknown cloud pulses, extends to all cloud pulses that appear not to fall distinctly into well defined categories. Unknown cloud pulses do not include any of the types listed above.

B. Specific Descriptions

Now that the general definitions have been discussed, this section gives more detailed descriptions. All of the following descriptions are based on the fast plots. The fast electric field serves as the main source of identification for each event, with the fast HF and dE/dt playing a supporting role. The descriptions will, in general, discuss the stepping structure before the peak, how rapidly the peak is attained, and the structure after the peak for each fast waveform.

A first return stroke preceded by a stepped leader (see time 226180000.072 for an example) has an electric field signature characterized by a slowly rising initial portion (front) before a fast transition to peak followed by a jagged section a few hundred microseconds in duration. This jagged section is believed to be produced by the superposition of radiation from the multiple branches evident in most photographs of first return

strokes (Weidman and Krider, 1978). Both the HF and the dE/dt waveforms exhibit spikes, corresponding to the leader steps, preceding a sharp peak followed by a relatively noisy section.

Dart-stepped subsequent return strokes (226174528.924) have shorter front durations before the fast transition to peak than first return strokes. The relatively smooth section of waveform after the peak, presumably due to an absence of branches, characterizes all types of subsequent return strokes. The dart-stepped leaders before these strokes tend to have more regular and shorter time intervals between steps than stepped leaders (Krider et al., 1977). The fast HF and dE/dt signatures exhibit spikes similar to first return strokes, corresponding to leader steps, before the sharp peak followed, in general, by a very quiet section.

Normal (226181138.648) and chaotic (226180544.448) subsequent return strokes are similar to dart-stepped subsequent return strokes except for the leader sections. Normal subsequent return strokes exhibit no indication of spikes before the abrupt transition to peak on any of the fast waveforms, indicative of a smoothly propagating dart leader. The leader activity on the fast E record prior to chaotic subsequent return strokes is irregular with closely spaced pulses of erratic amplitude behavior. There is also evidence of this type of activity on both the fast HF and dE/dt waveforms of chaotic leaders. When the leader amplitudes are near the system noise level, the difference between dart and chaotic leaders is difficult to ascertain. The distinction between them is thus somewhat subjective, leaving open the question of whether they are really different physical phenomena.

The other three types of return strokes defined here are of a hybrid nature. They occur fairly rarely with respect to the types described

above. The waveforms of <u>Anomalous #1</u> (226180000.175) <u>return strokes</u> start out like first return strokes but quickly become smooth, whereas <u>Anomalous #2</u> (226175829.133) <u>return strokes</u> start out like a subsequent stroke but end up jagged. Decay of the first return stroke's channel during the interval between strokes suggests a plausible explanation for Anomalous #1 return strokes. The lower section of the channel has more time to decay than the upper section. Presumably the dart-stepped leader follows the same channel as the stepped leader at higher altitudes, without branching, but forms a new channel at lower altitudes, with branching. Because the return stroke propagates from the ground toward the cloud, this scenario would suggest a waveform similar to that seen in Anomalous #1 return strokes. The waveform of Anomalous #2 return strokes suggests branches at higher altitudes and the absence of branches at lower altitudes. The explanation for this type of waveform is not known. A <u>multiple ground</u> (205200917.206) <u>return stroke</u> exhibits two sharp transitions to peak and looks like two first return stroke waveforms superimposed. This type is assumed to originate from two almost simultaneous return strokes initiated by different branches of the same stepped leader (Guo and Krider, 1982).

Unlike return strokes, which have the same general shape among categories, cloud pulses are more varied. Beasley et al. [1982] believe that <u>characteristic pulses</u> (226174950.465) probably occur before all stepped leaders associated with first return strokes. They state that these bipolar pulses with negative initial polarity (our sign convention) occur in groups during a transition period of a few milliseconds between when the "preliminary variations" end and stepped leader begins. Our recordings also indicate that characteristic pulses usually occur in groups. Each

individual pulse (see the expanded fast E record) tends to exhibit several narrow spikes on a slow rise to peak followed by a smooth overshoot. NPBPs (205203928.628) are most easily distinguished by their electric field derivative, which contains high frequency oscillations superposed upon a slower variation of initially positive then negative polarity. The magnitude of the positive and negative peak is usually nearly the same. The electric field structure typically has a fast positive rise and decay followed by a small negative overshoot. NPBPs appear to be isolated events; seldom is any other slow HF peak found during the same "flash". A range of 45 Km was assumed for them because they were recorded during the isolated and localized storm on 07/24/85. NNBPs (205203429.863) are nearly identical to NPBPs except the polarity is reversed (Willett et al., 1989). Unknown cloud pulses (226173216.949) are included because they appear to be associated with the cloud to ground flash.

V. OBSERVATIONS AND CONCLUSIONS

Fast (10 and 100 ns/sample) and slow (50 μsec/sample) time domain waveforms are plotted for all the located flashes which occurred on July 24 and August 14, 1985. Each event within the lightning flash has been classified into one of 15 categories (see section IV). Three categories have been added to those discussed by earlier investigators. Anomalous #1 and Anomalous #2 return strokes appear to be hybrid strokes that contain some features of both first and dart-stepped subsequent return strokes. Unknown cloud pulses are events that we could not identify. Their waveforms, to the author's knowledge, have not been discussed in the literature.

Subsequent reports will follow and may include more than the 15 categories defined herein.

So far we have identified 65 first, 23 dart-stepped subsequent, 8 normal subsequent, 8 chaotic subsequent, 4 anomalous #1, 1 anomalous #2, and 5 multiple ground return strokes. These return strokes all have leader processes preceding them. For leaders that did not exhibit a peak in the dE/dt record corresponding to the return stroke fast transition, an additional 9 stepped, 1 dart-stepped, 0 dart, and 1 chaotic leaders were identified. In the cloud pulse categories, 17 characteristic, 18 narrow positive bipolar (NPBP), 2 narrow negative bipolar (NNBP), and 2 unknown cloud pulses were identified.

One simple analysis was performed in an attempt to determine whether characteristic pulses precede all first return strokes as suggested by Beasley et al. [1982]. These authors state that preliminary variations start, on the average, 118 msec before the return stroke peak for an average duration of 90 ms. Characteristic pulses that occur in the transition period between when preliminary variations end and stepped leaders begin would therefore start, on the average, approximately 28 ms before the first return stroke peak.

First return strokes can be identified either directly from the fast waveforms or by inspection of the electrostatic field change seen in the slow E record caused by charge transfer by the stepped leader. The occurrence of a peak in the slow HF record before the first return stroke peak might be indicative of characteristic pulses. In 1985, the dead time between high resolution events was too great to trigger on both the characteristic pulse and the first return stroke; therefore, the identification

of the preceding characteristic pulse is often uncertain. Given these uncertainties, characteristic pulses were assumed present before the first return stroke as long as there was evidence of both stepped leader activity on the slow E and a slow HF peak near the same time as the start of the leader activity. If a slow HF peak did not occur near the start of the stepped leader, then this case was classified as not having a characteristic pulse. Because of the reduction in the dead time, the 1987 data is better but has not been analyzed yet.

The results are inconclusive. Out of 81 possible reliable cases of first return strokes, 46 of them contained the required HF radiation; however, there appeared to be a strong range bias. Figure 6 shows histograms for the number of cases with and without HF radiation indicative of characteristic pulses prior to the return stroke as a function of range. There is a clear bias toward shorter ranges for the cases with HF radiation. Any attenuation due to propagation effects would be expected to be greater for the return stroke (lower source altitude) than for the characteristic pulse, in contradiction to the observed result. The explanation for this bias is not readily apparent. As a result, it is unclear whether the lack of HF radiation on the remaining 35 cases is due to low signal level or indicates that characteristic pulses do not always precede first return strokes. The characteristic pulses preceded the first return stroke peak radiation from 8 to 60 ms with an average of 21 ± 12 ms in agreement with the results of Beasley et al. [1982].

One flash is worthy of mentioning because of special circumstances. The "flash", as defined by the slow digitizers, at time 18:34:51.311 on August 14, 1985 is actually two separate flashes located at different

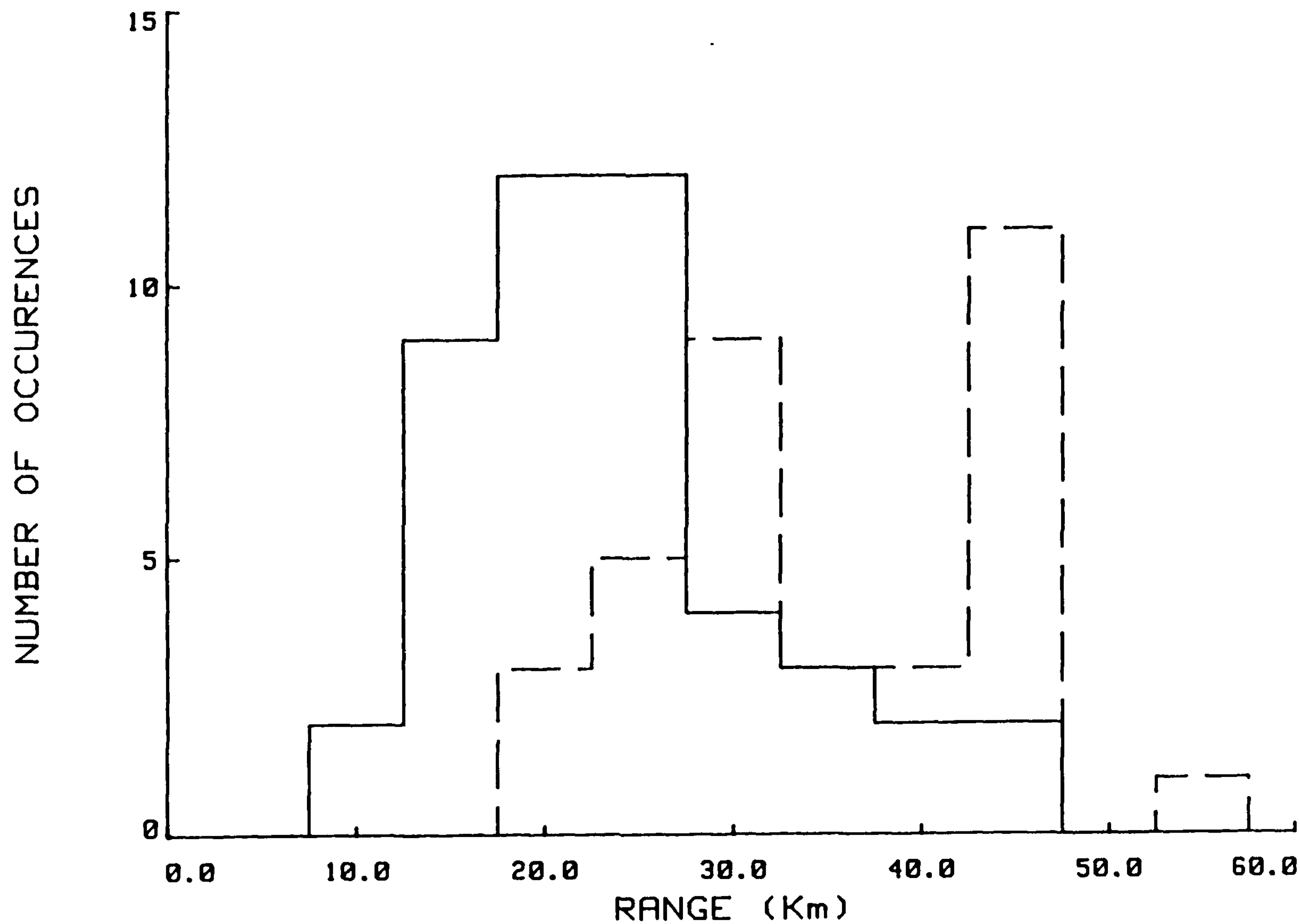

FIG. 6 -- Histograms of the number of 1st return strokes with (solid) and without (dashed) a slow HF peak before the return stroke peak as a function of range. The presence of the slow HF peak could be an indication of a characteristic pulse (see text).

ranges. Each event within the flash has been range normalized to its appropriate range, whereas the slow HF has been range normalized to the later event's range.

VI. ACKNOWLEDGEMENTS

Lightning locations were kindly provided by E.P. Krider. Kennedy Space Center, in particular W. Jafferis, provided many types of ground support essential to the successful completion of the experiment. C. Leteinturier of CNET, France, assisted in the operation of the equipment during the 1985 field experiment. M. Gomez helped prepare some of the plots. J. Shertzer helped prepare the document. This work was supported in part by AFOSR contract F49620-86-C-0013.

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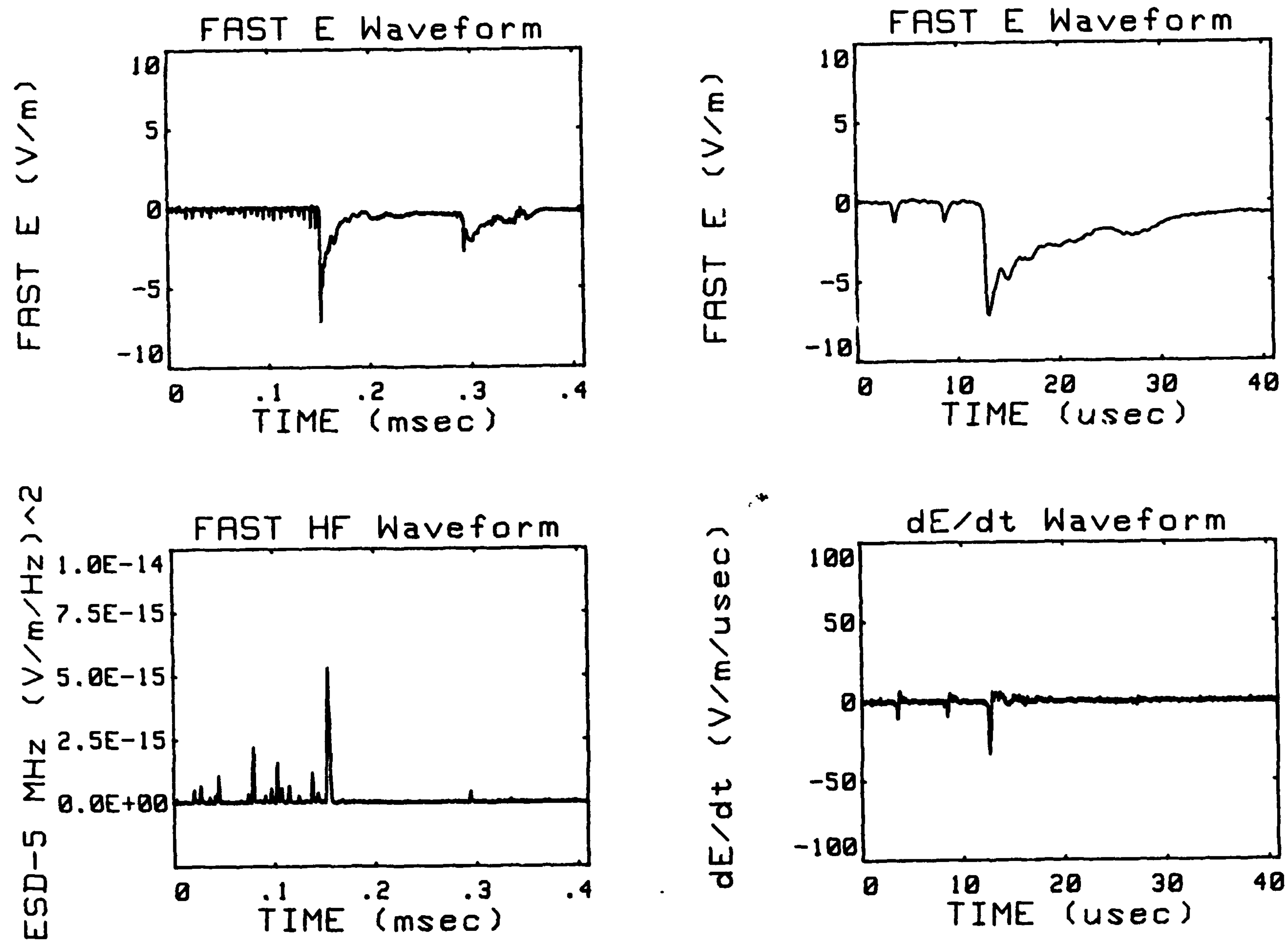
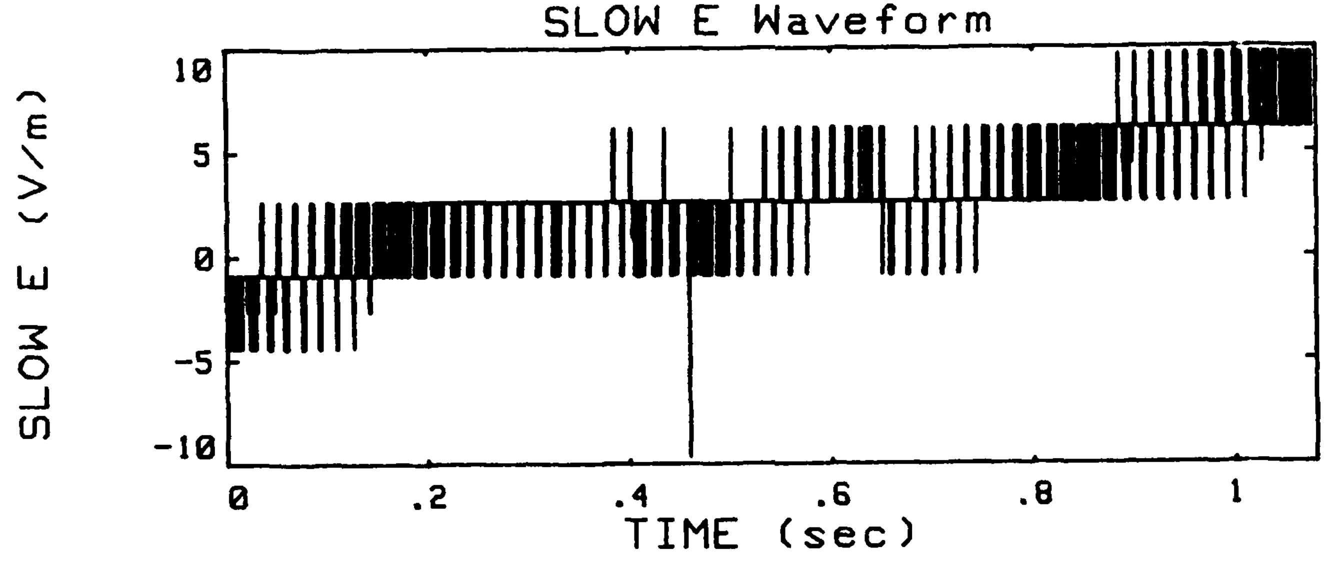
APPENDIX A

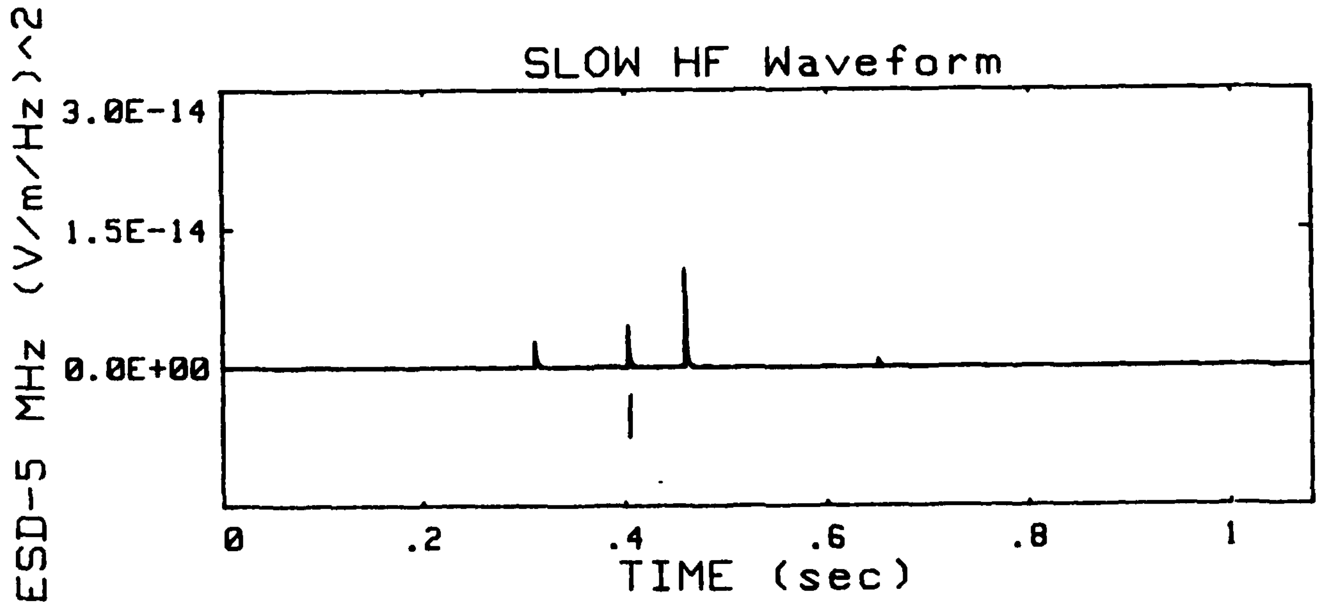
July 24 Data Plots

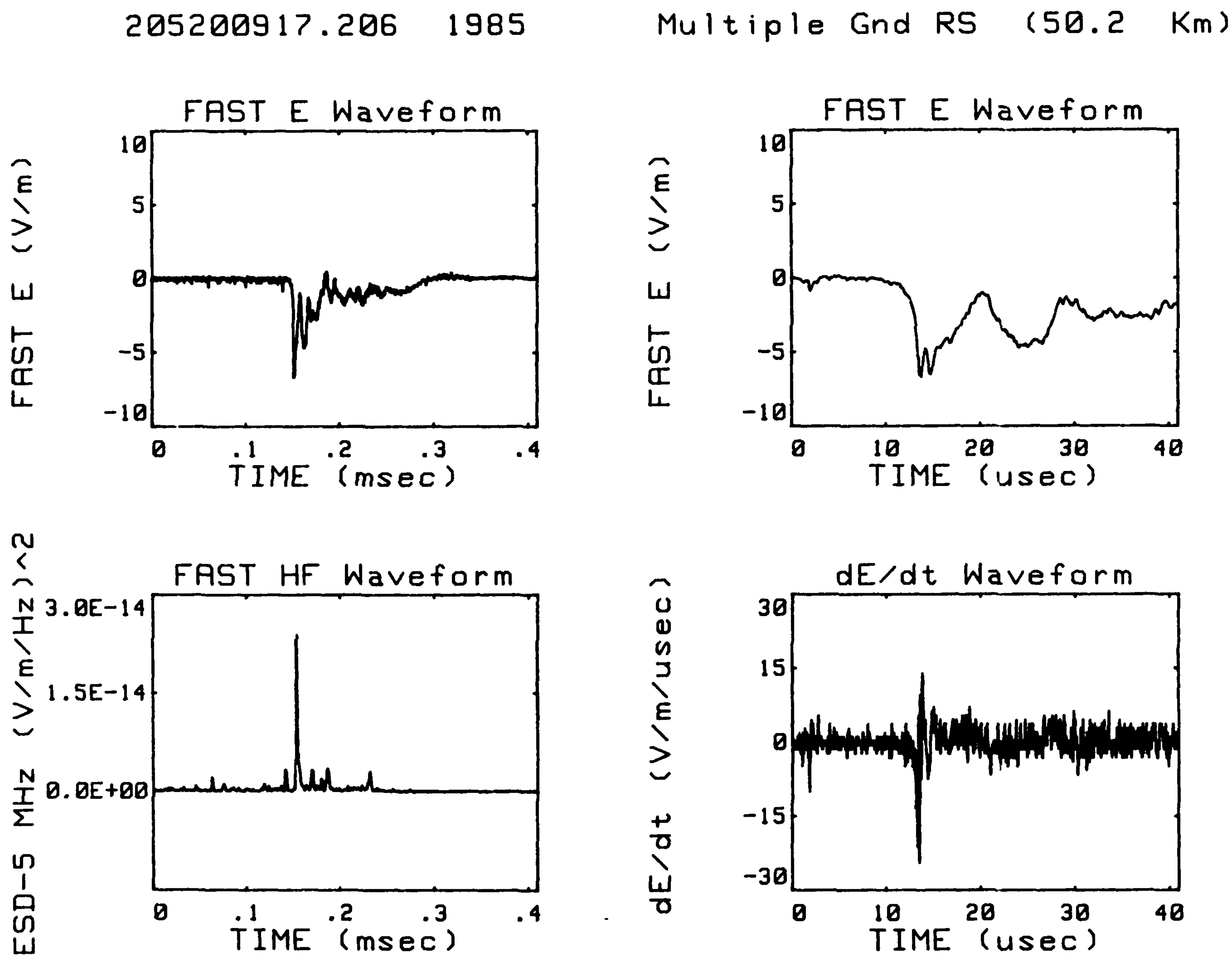
205200723.309 1985 DS Subs RS (45.6 Km)



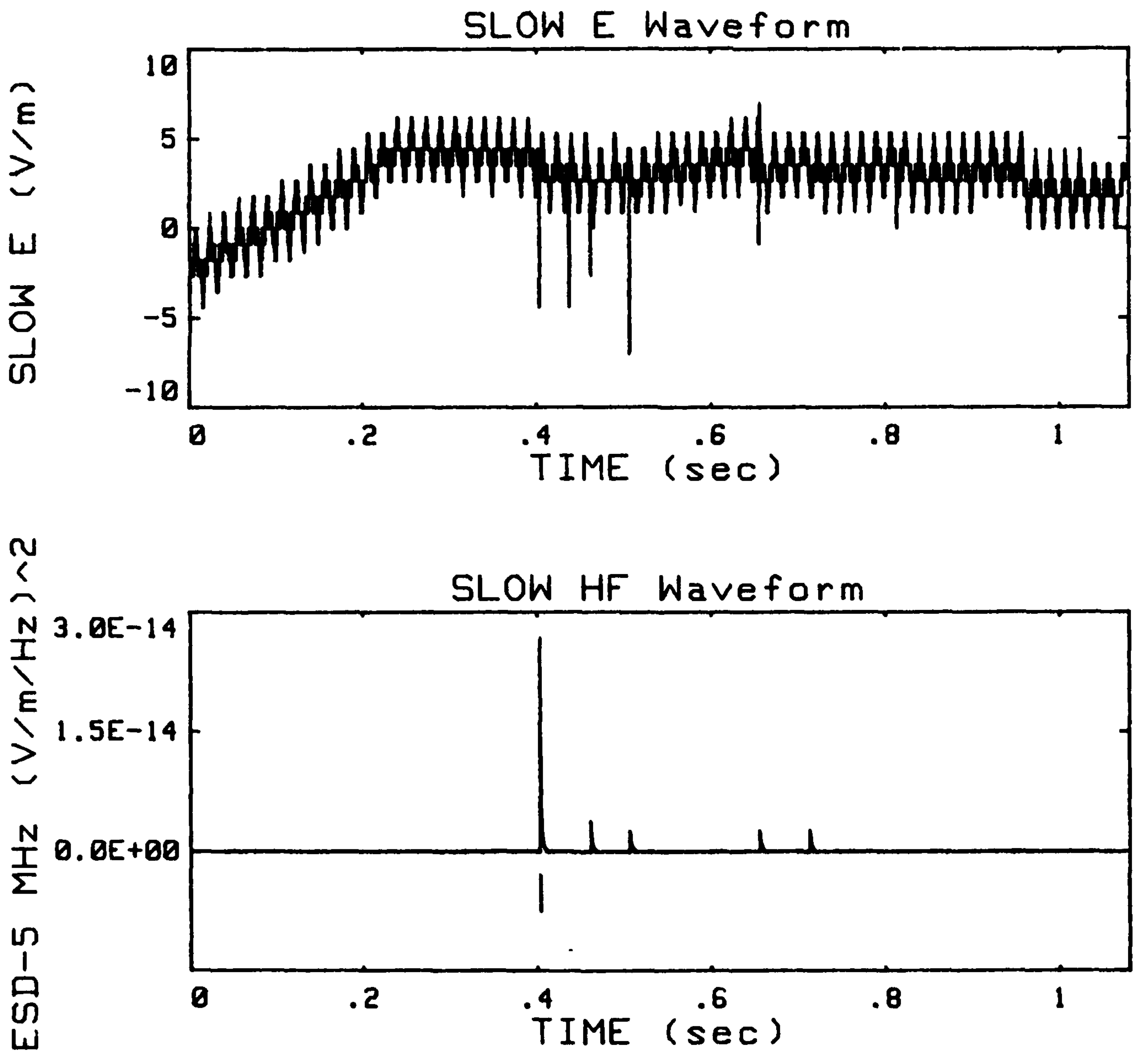
20:07:22.917 24 Jul 1985 (45.6 Km)

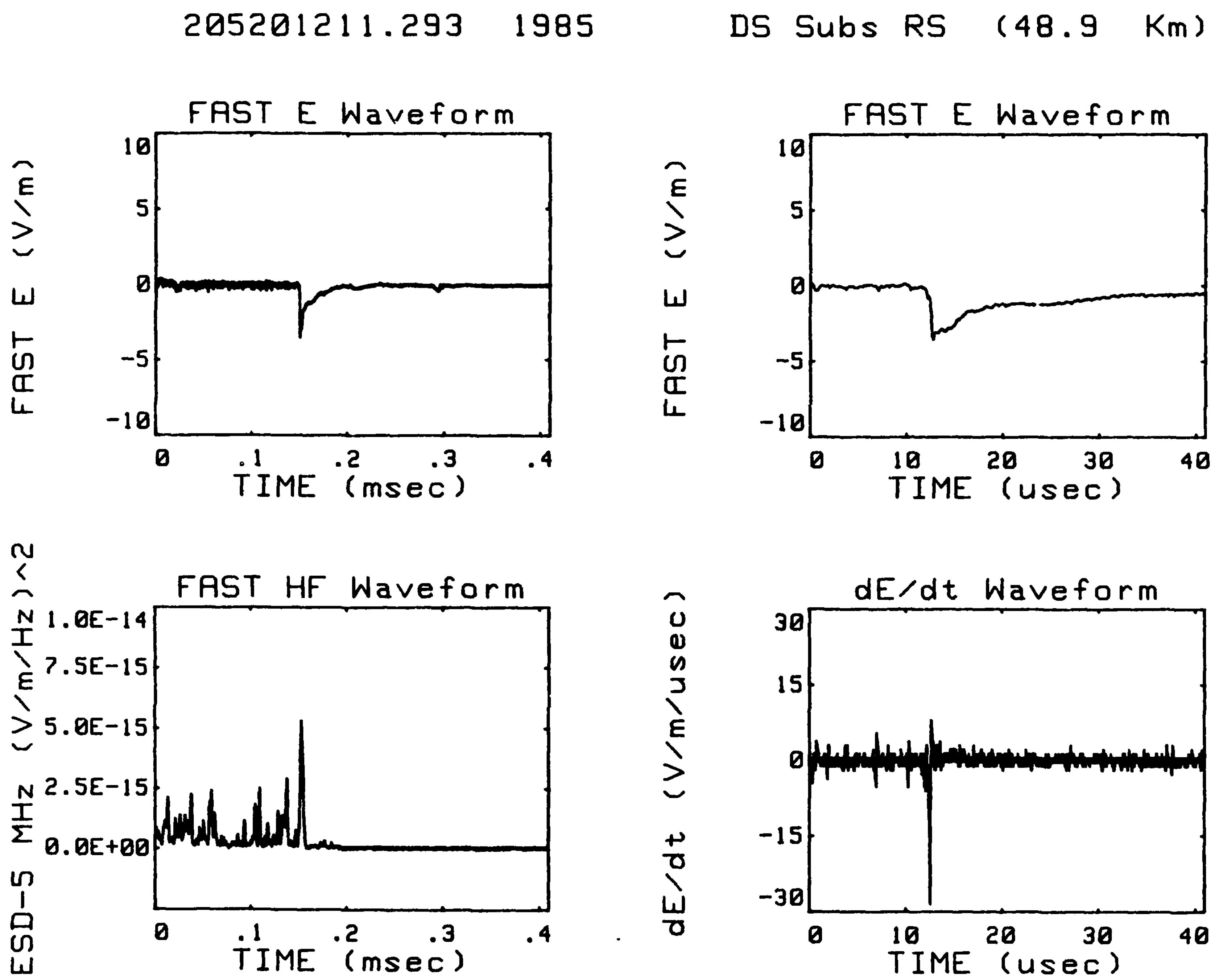




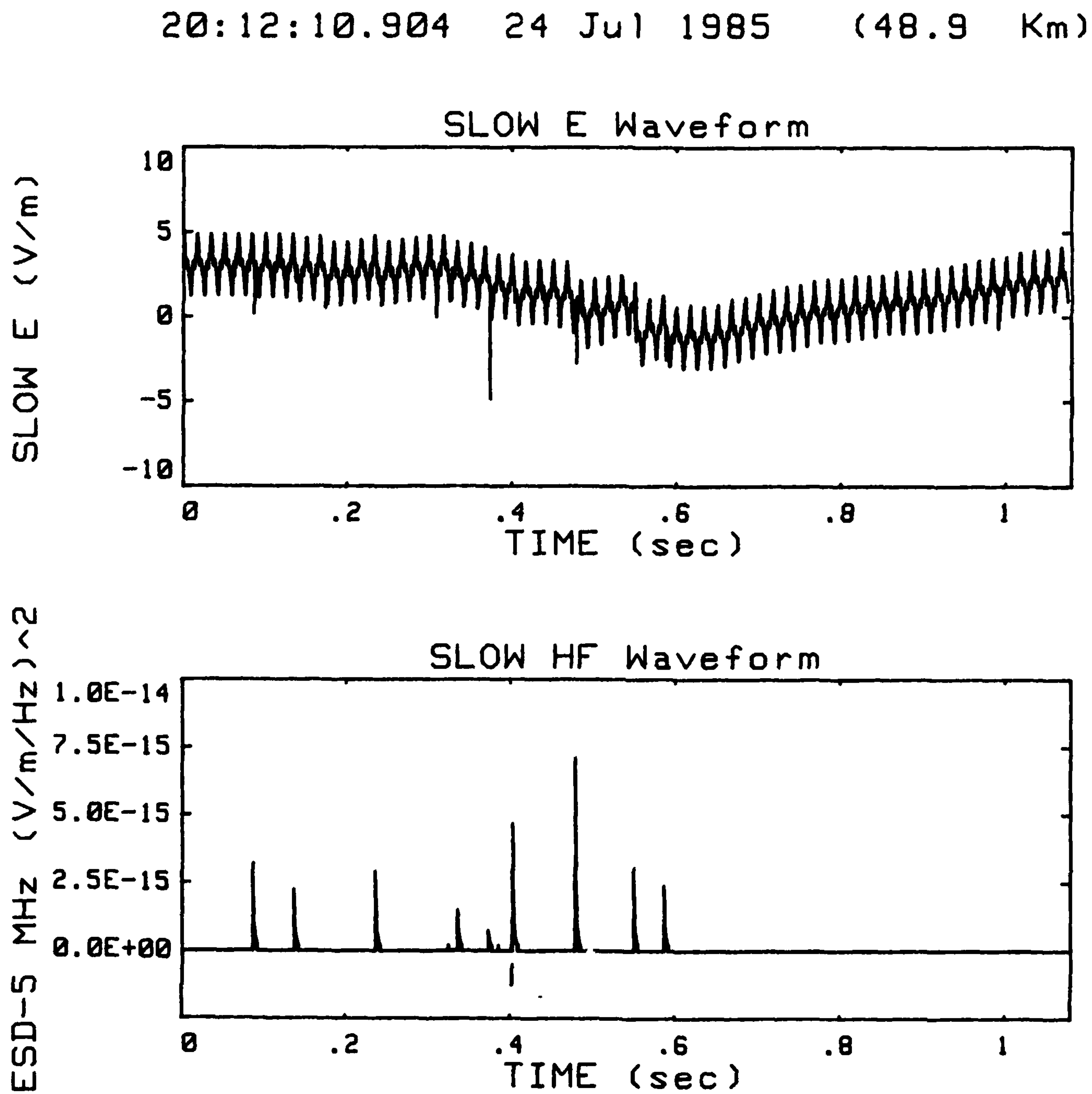

205200917.206 1985
Multiple Gnd RS (50.2 Km)
FAST E Waveform
FAST E (V/m)
10
5
0
-5
-10
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
10
5
0
-5
-10
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
3.0E-14
1.5E-14
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
30
15
0
-15
-30
0
10
20
30
40
TIME (usec)

20:09:16.815 24 Jul 1985 (50.2 Km)

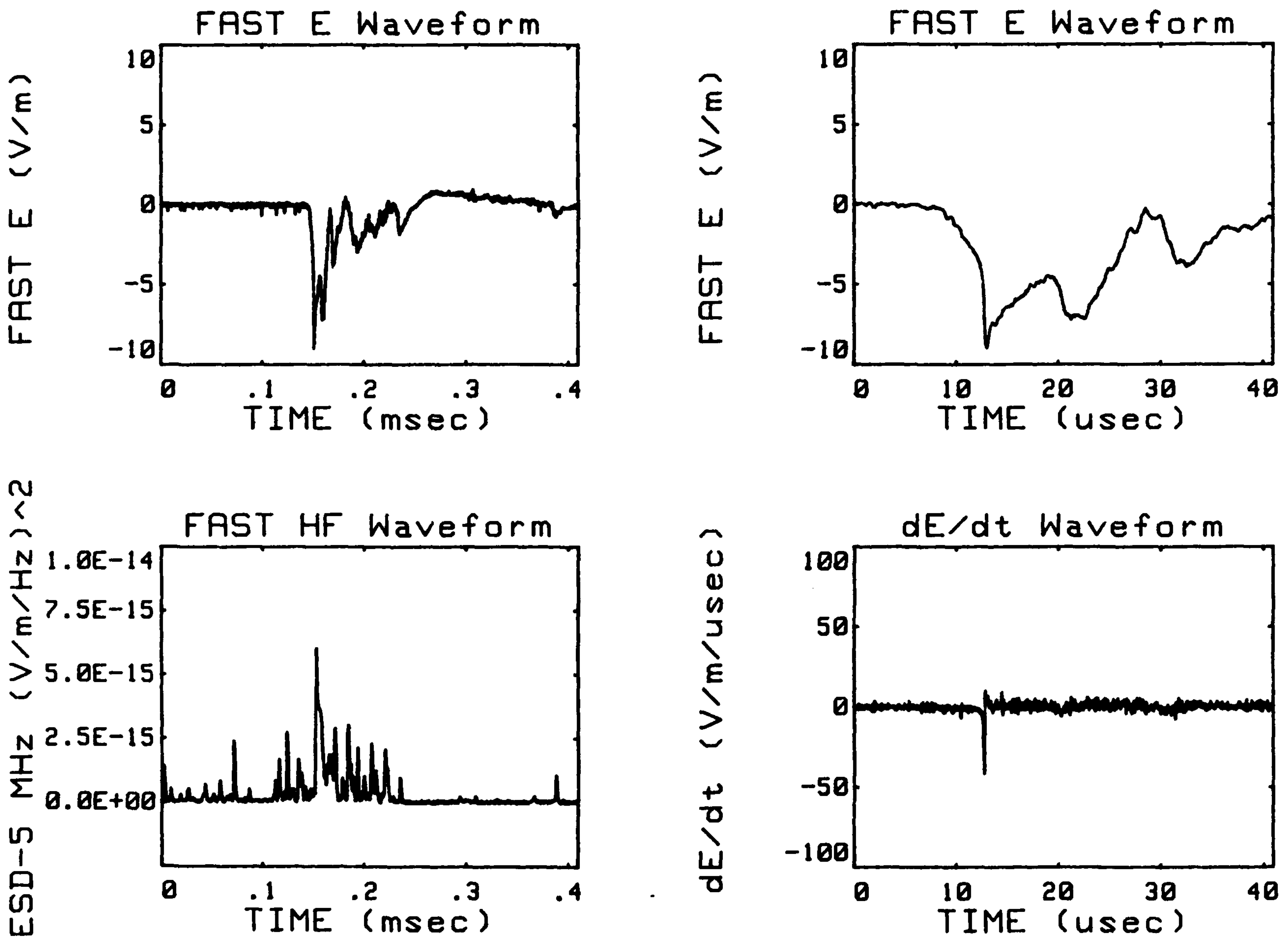




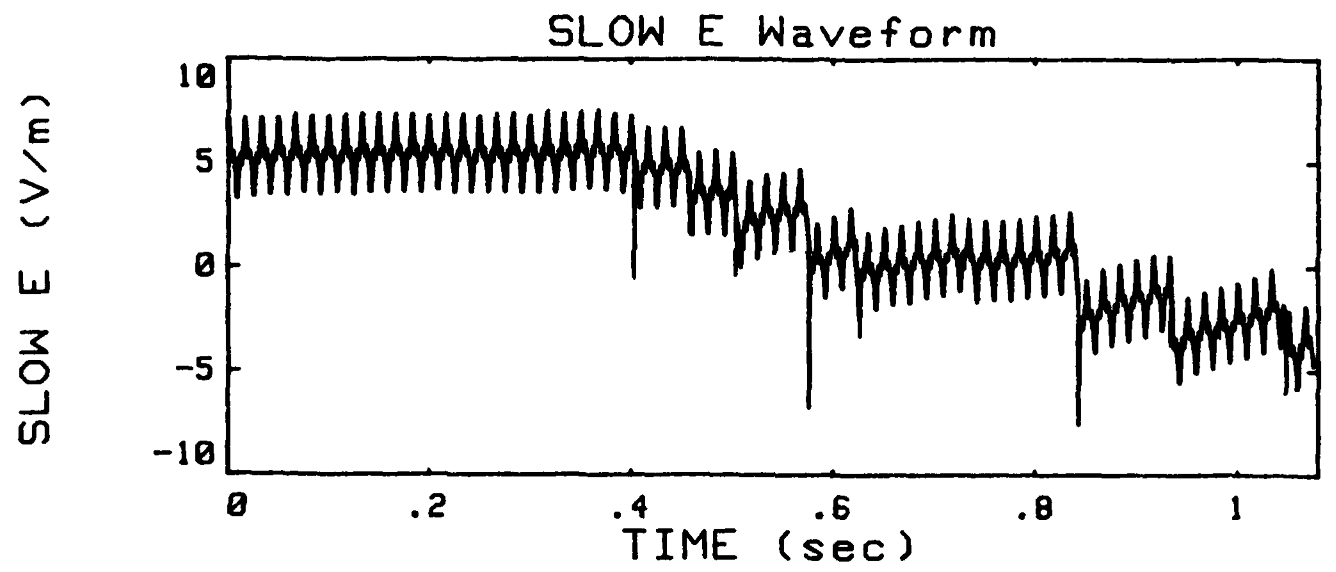
205201211.293 1985
DS Subs RS (48.9 Km)
FAST E Waveform
FAST E (V/m)
10
5
0
-5
-10
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
10
5
0
-5
-10
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
1.0E-14
7.5E-15
5.0E-15
2.5E-15
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
30
15
0
-15
-30
0
10
20
30
40
TIME (usec)

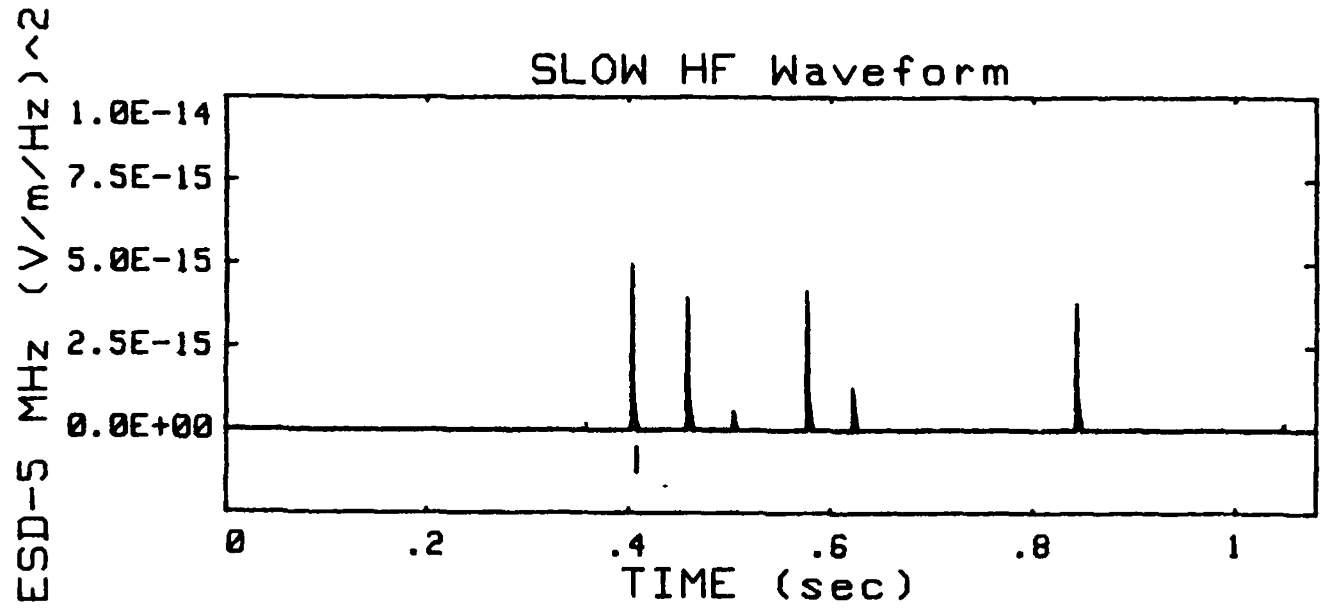

20:12:10.904 24 Jul 1985 (48.9 Km)
SLOW E Waveform
SLOW E (V/m)
10
5
0
-5
-10
0
.2
.4
.6
.8
1
TIME (sec)
SLOW HF Waveform
ESD-5 MHz (V/m/Hz)^2
1.0E-14
7.5E-15
5.0E-15
2.5E-15
0.0E+00
0
.2
.4
.6
.8
1
TIME (sec)

205201306.572 1985 1st RS (46.7 Km)

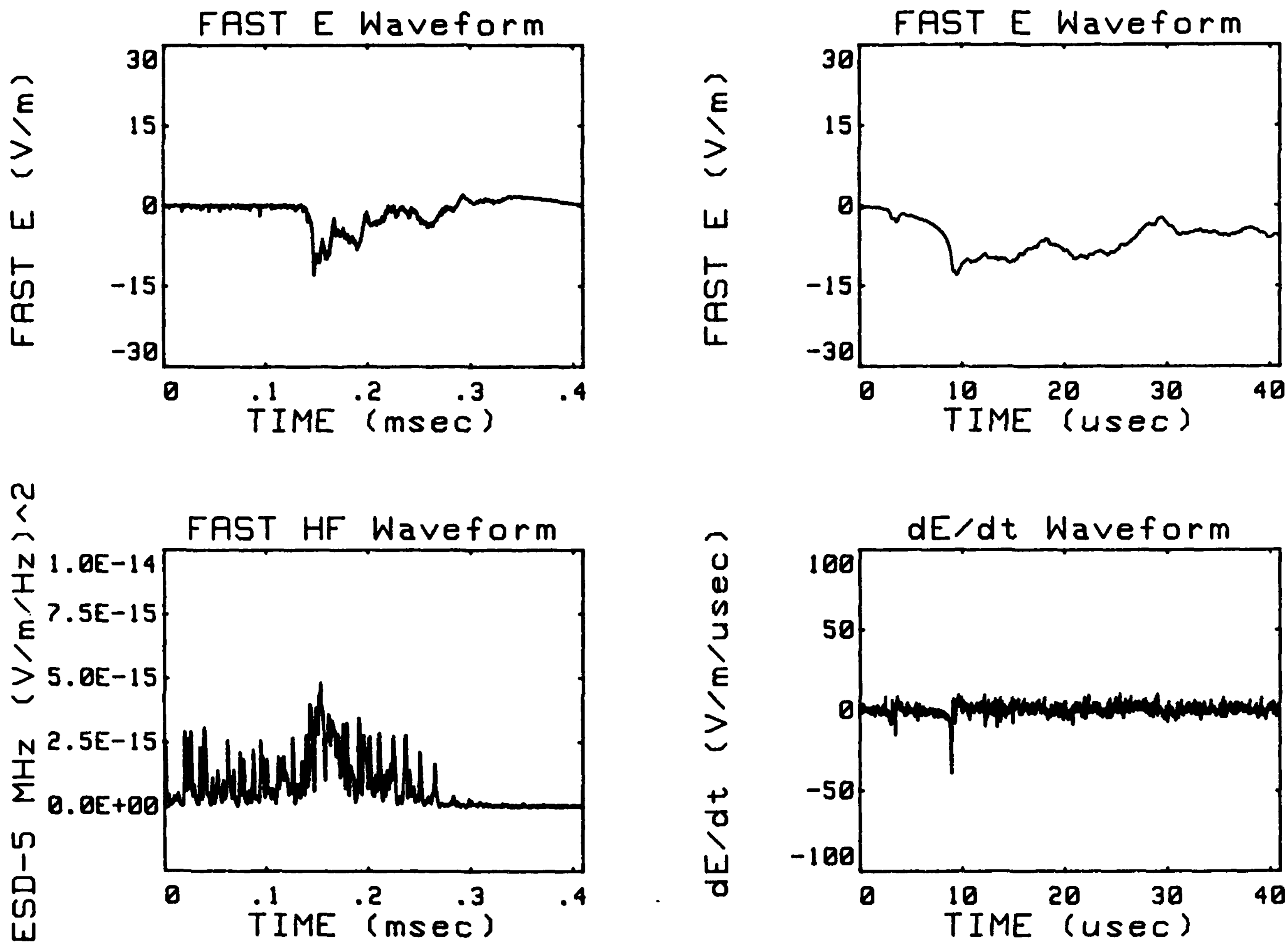


20:13:06.177   24 Jul 1985   (46.7 Km)

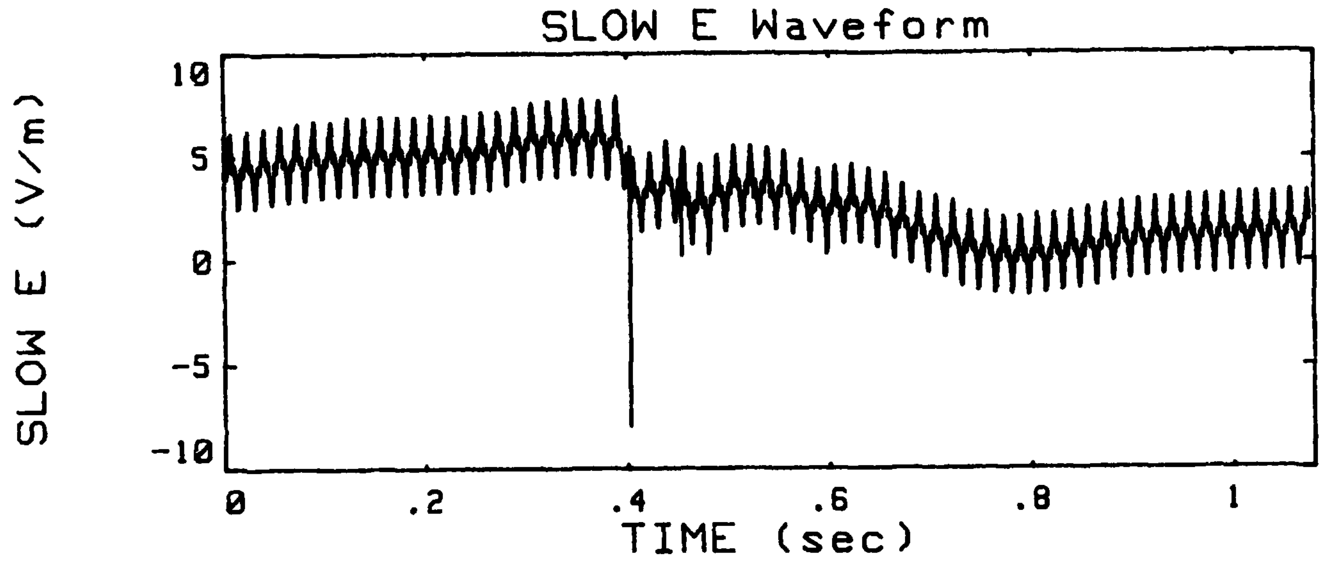


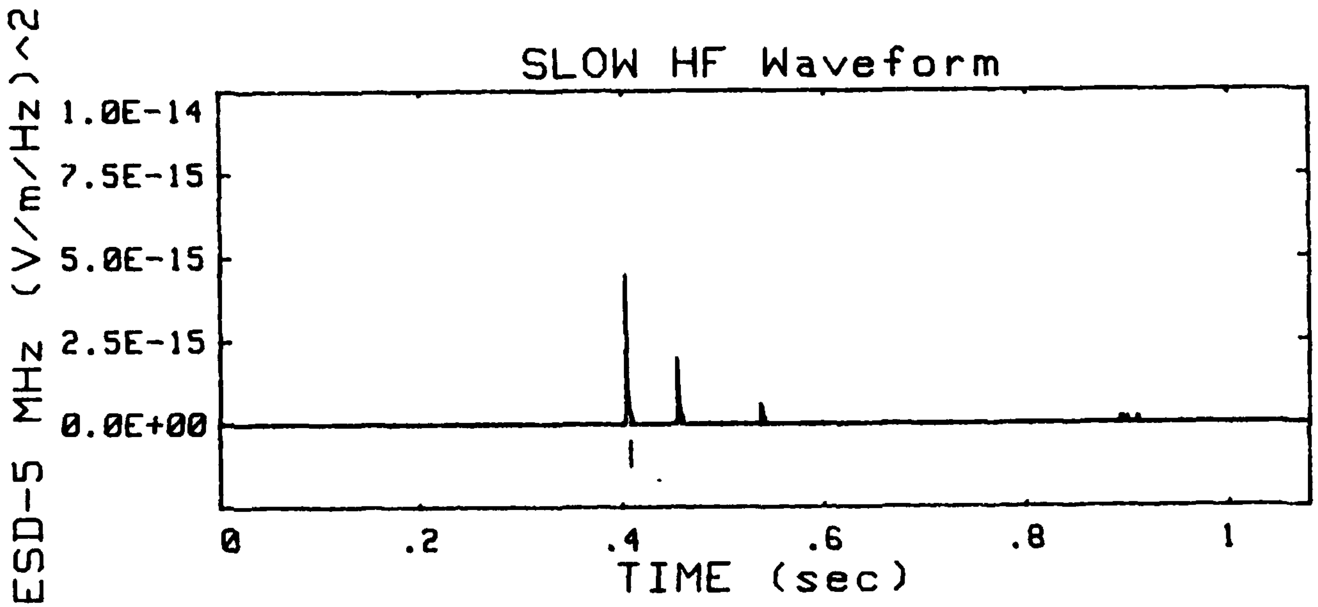


205201449.822 1985 1st RS (46.7 Km)

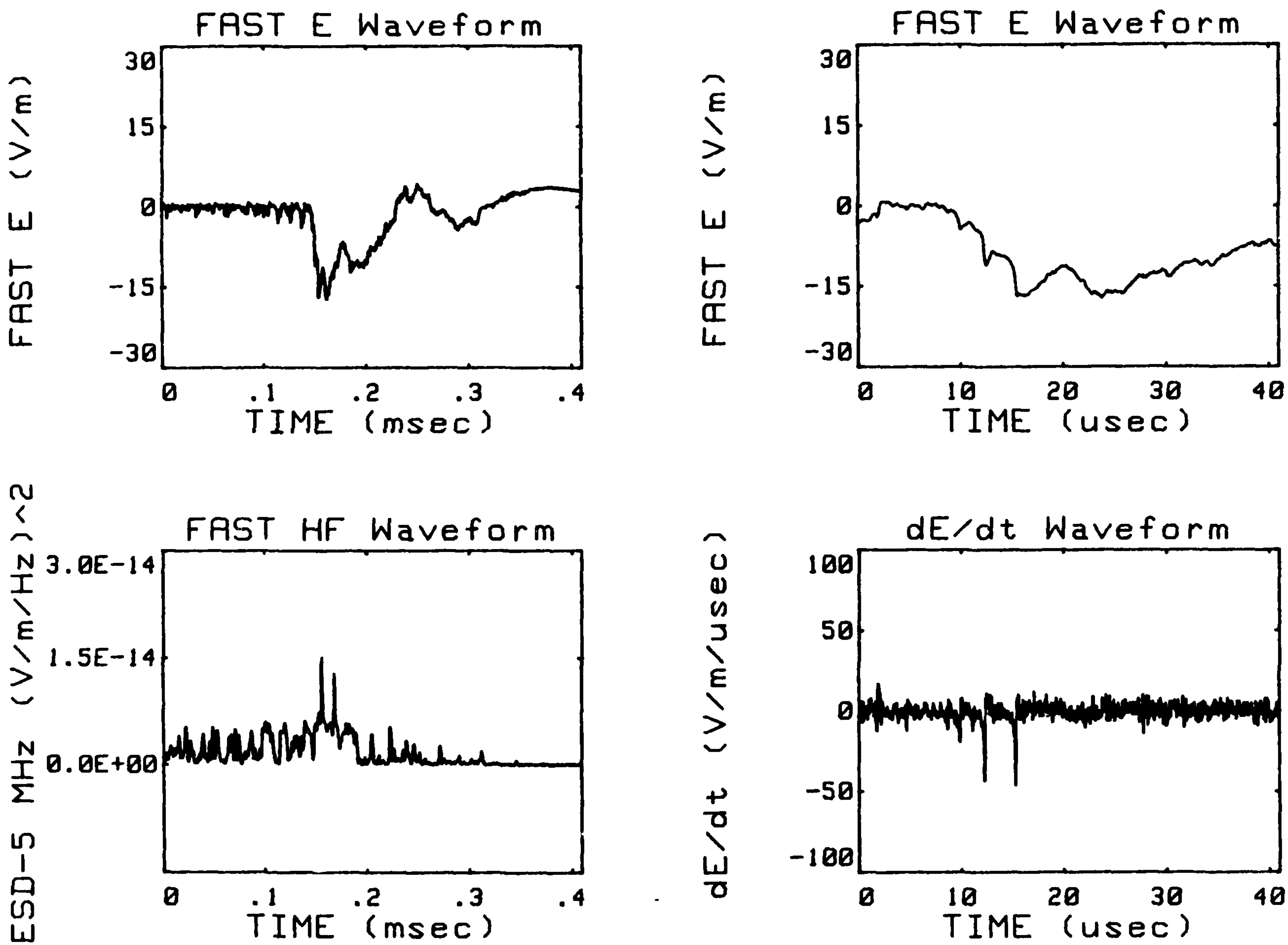


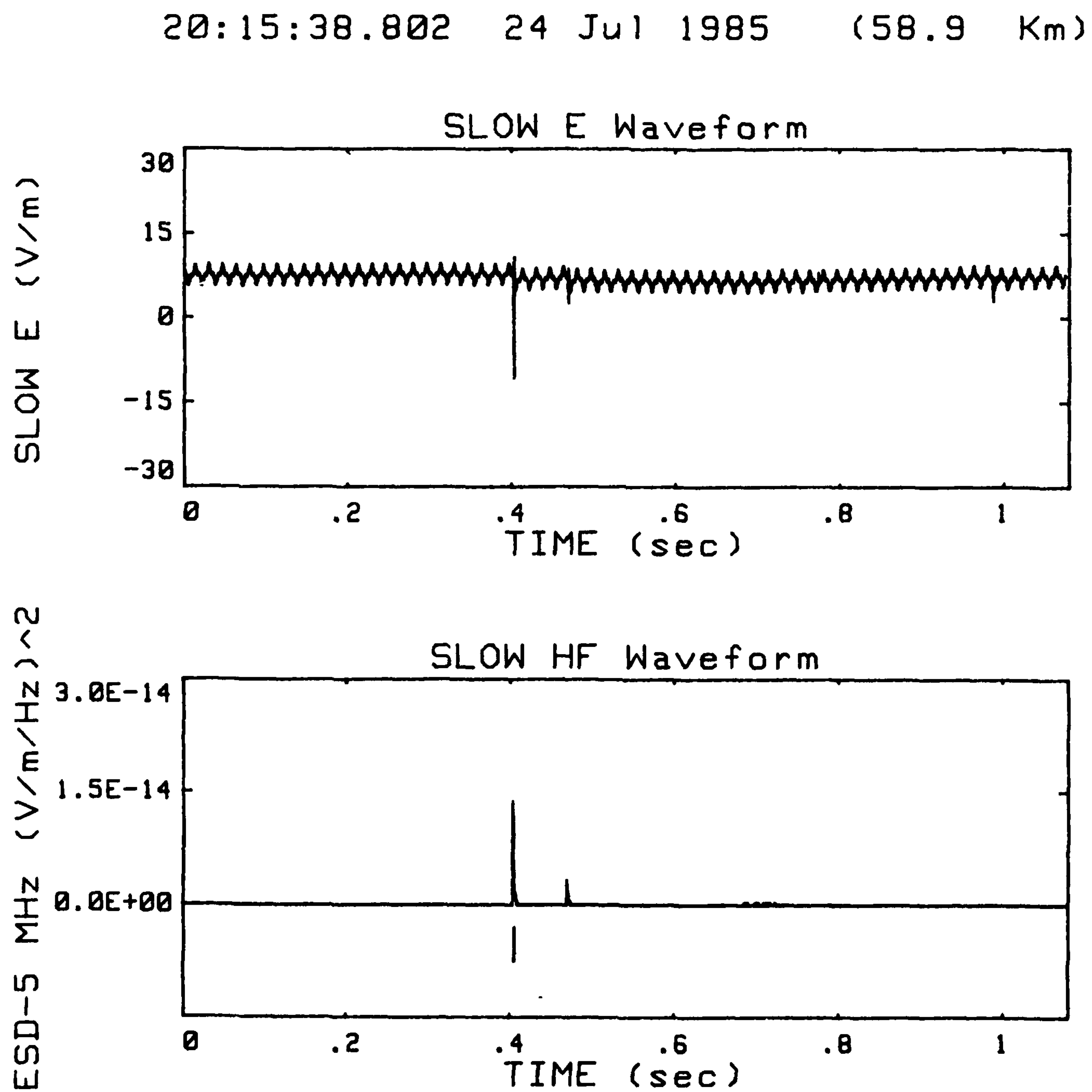
20:14:49.427 24 Jul 1985 (46.7 Km)



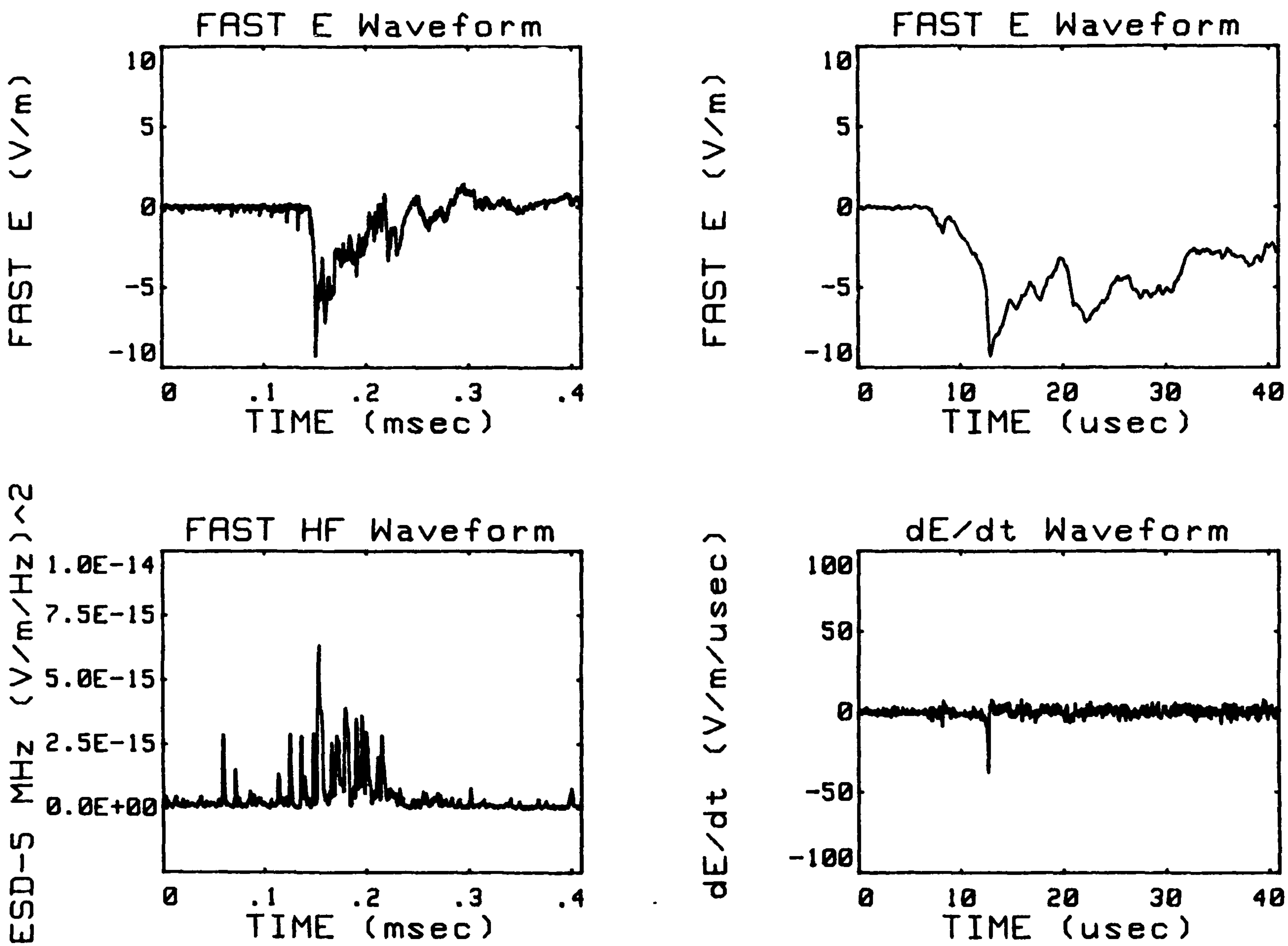


205201539.194 1985 1st RS (58.9 Km)

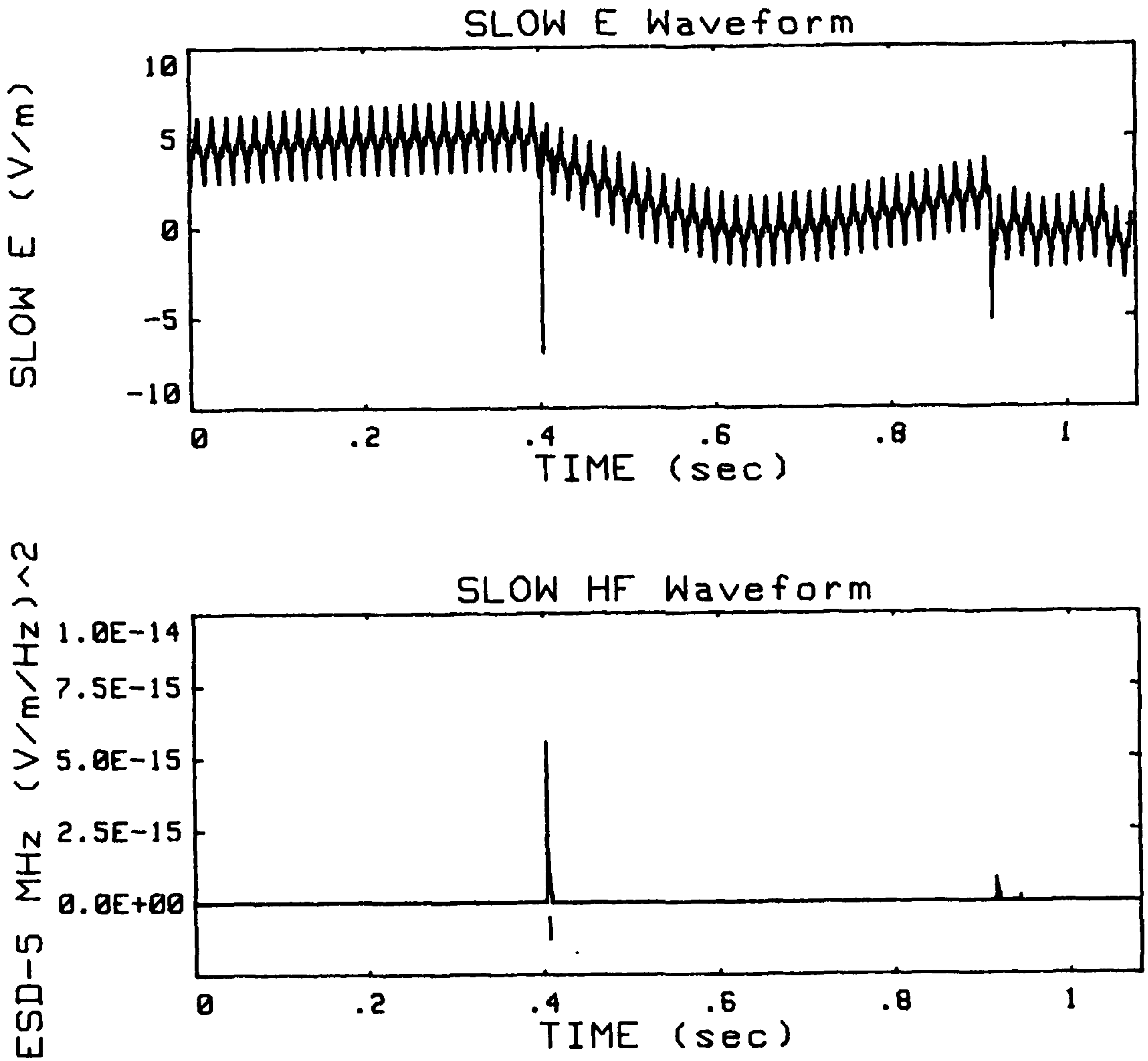


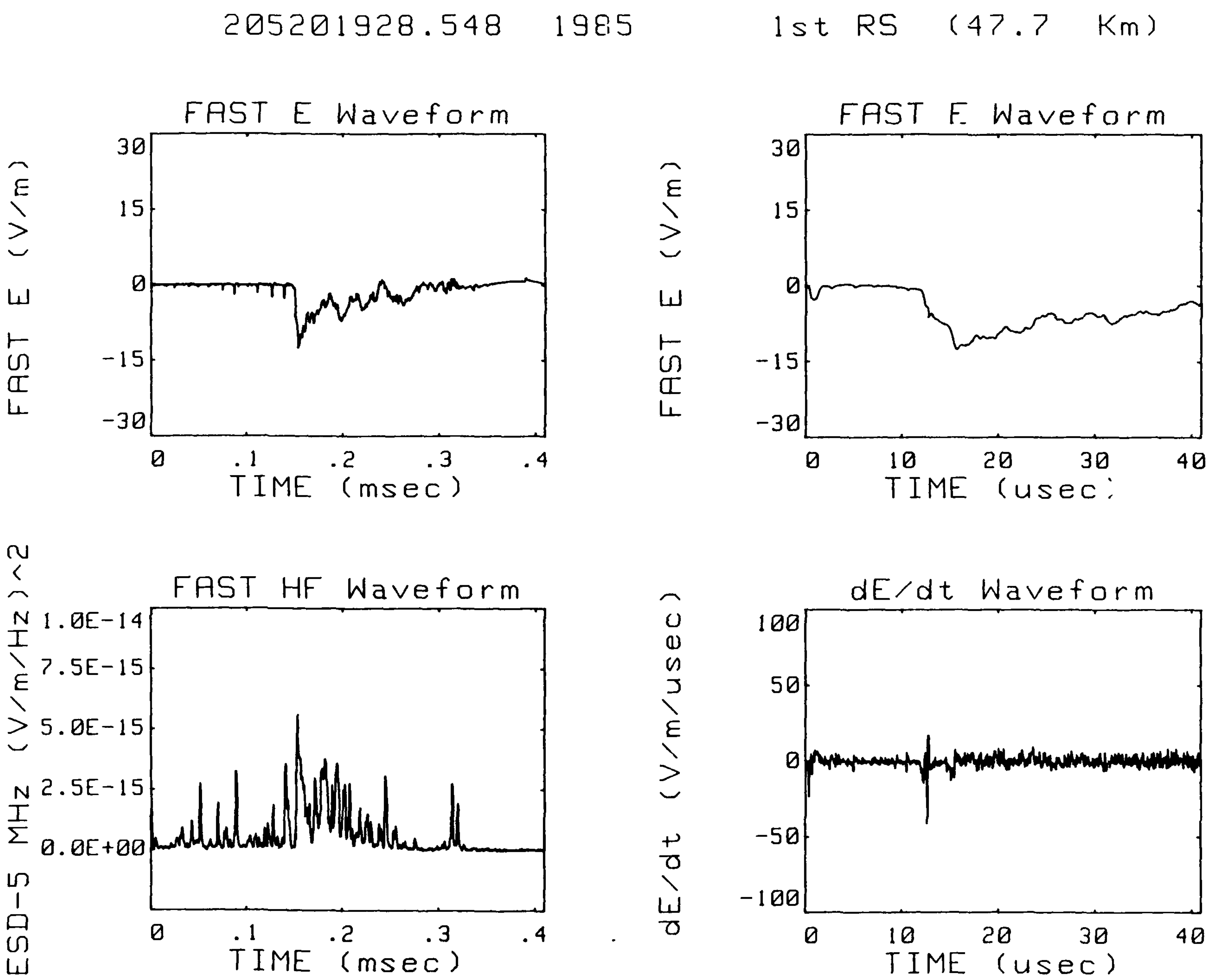

20:15:38.802 24 Jul 1985 (58.9 Km)
SLOW E Waveform
SLOW E (V/m)
30
15
0
-15
-30
0
.2
.4
.6
.8
1
TIME (sec)
SLOW HF Waveform
ESD-5 MHz (V/m/Hz)^2
3.0E-14
1.5E-14
0.0E+00
0
.2
.4
.6
.8
1
TIME (sec)

205201914.397 1985 1st RS (48.2 Km)



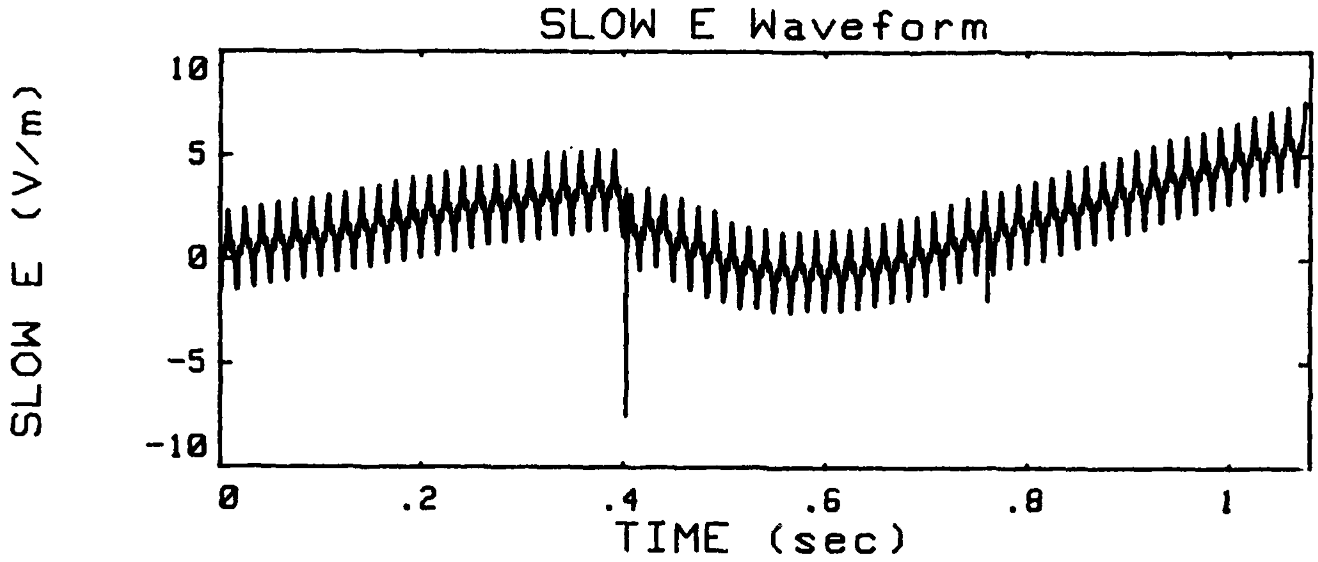
20:19:14.004 24 Jul 1985 (48.2 Km)

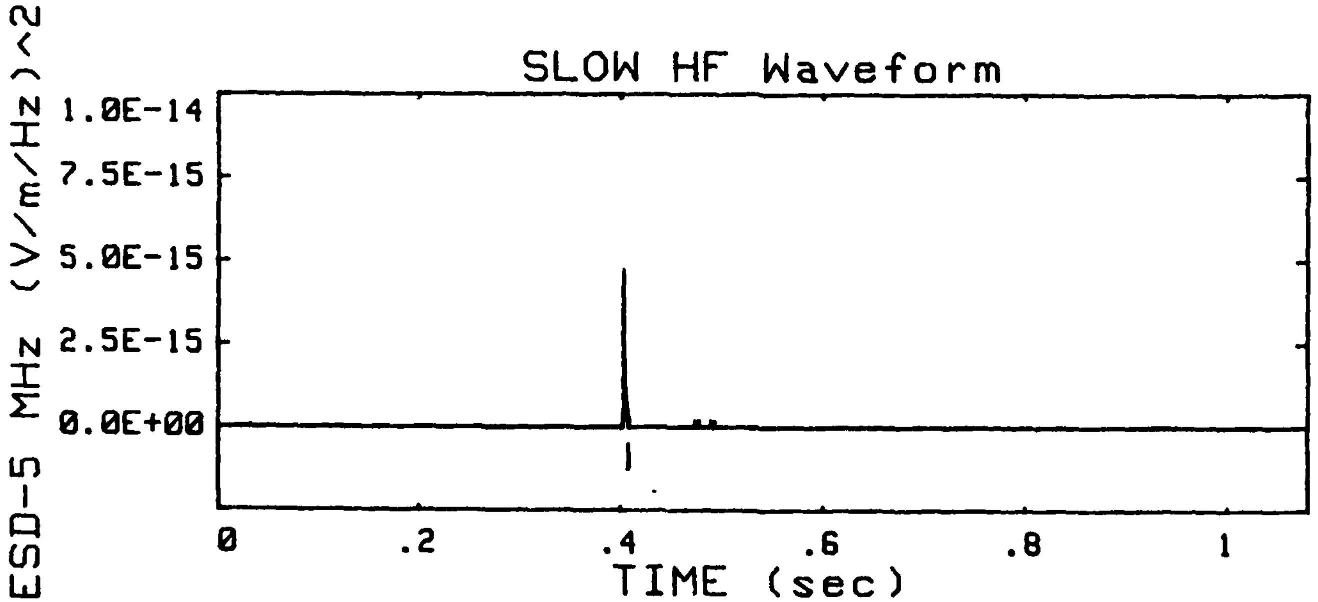




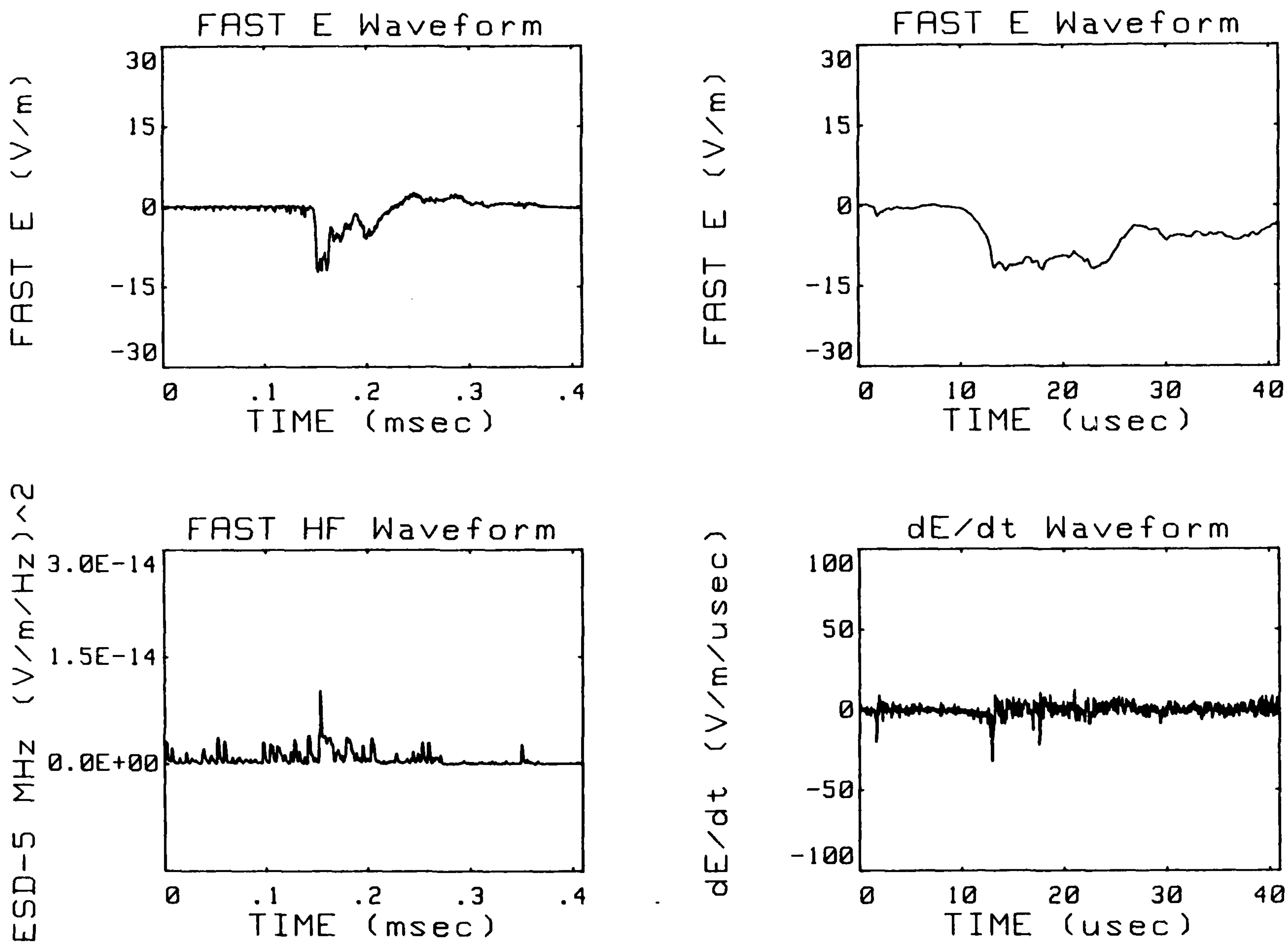
205201928.548 1985
1st RS (47.7 Km)
FAST E Waveform
FAST E (V/m)
30
15
0
-15
-30
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
30
15
0
-15
-30
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
1.0E-14
7.5E-15
5.0E-15
2.5E-15
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
100
50
0
-50
-100
0
10
20
30
40
TIME (usec)

20:19:28.153 24 Jul 1985 (47.7 Km)

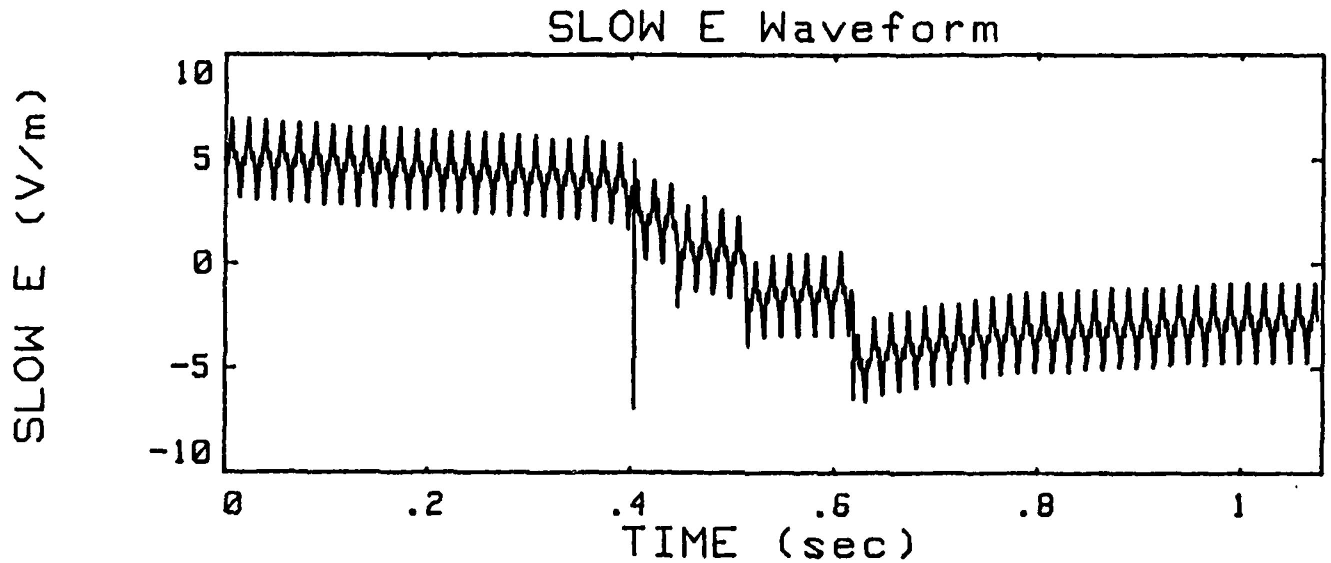


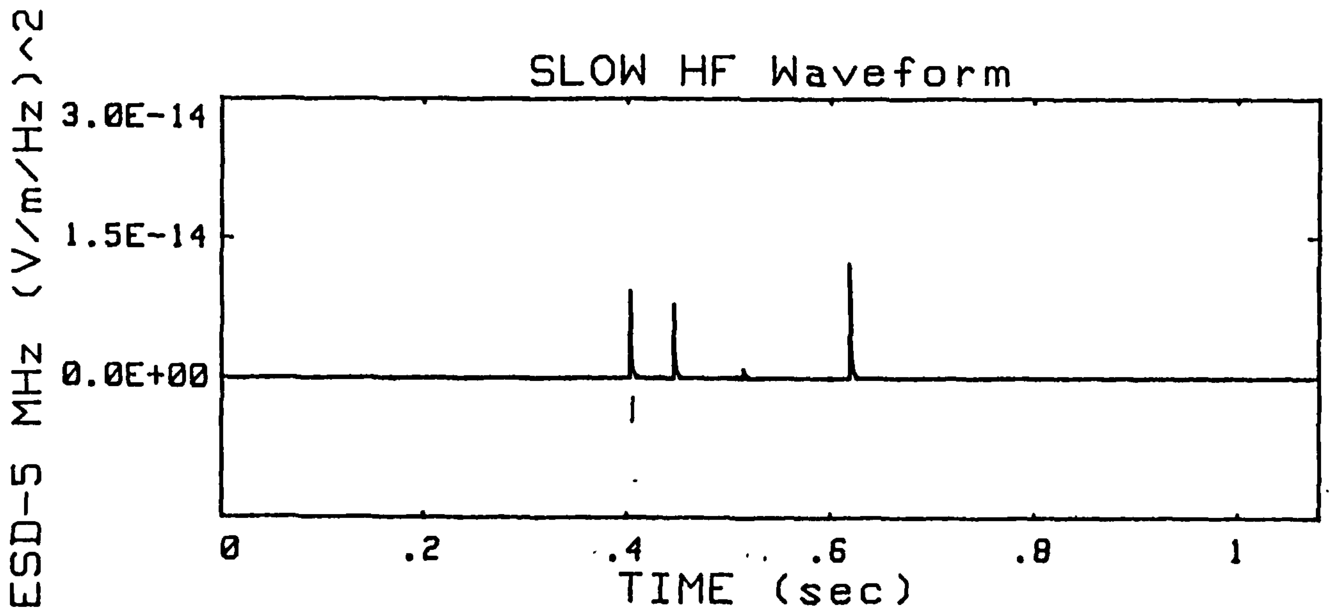


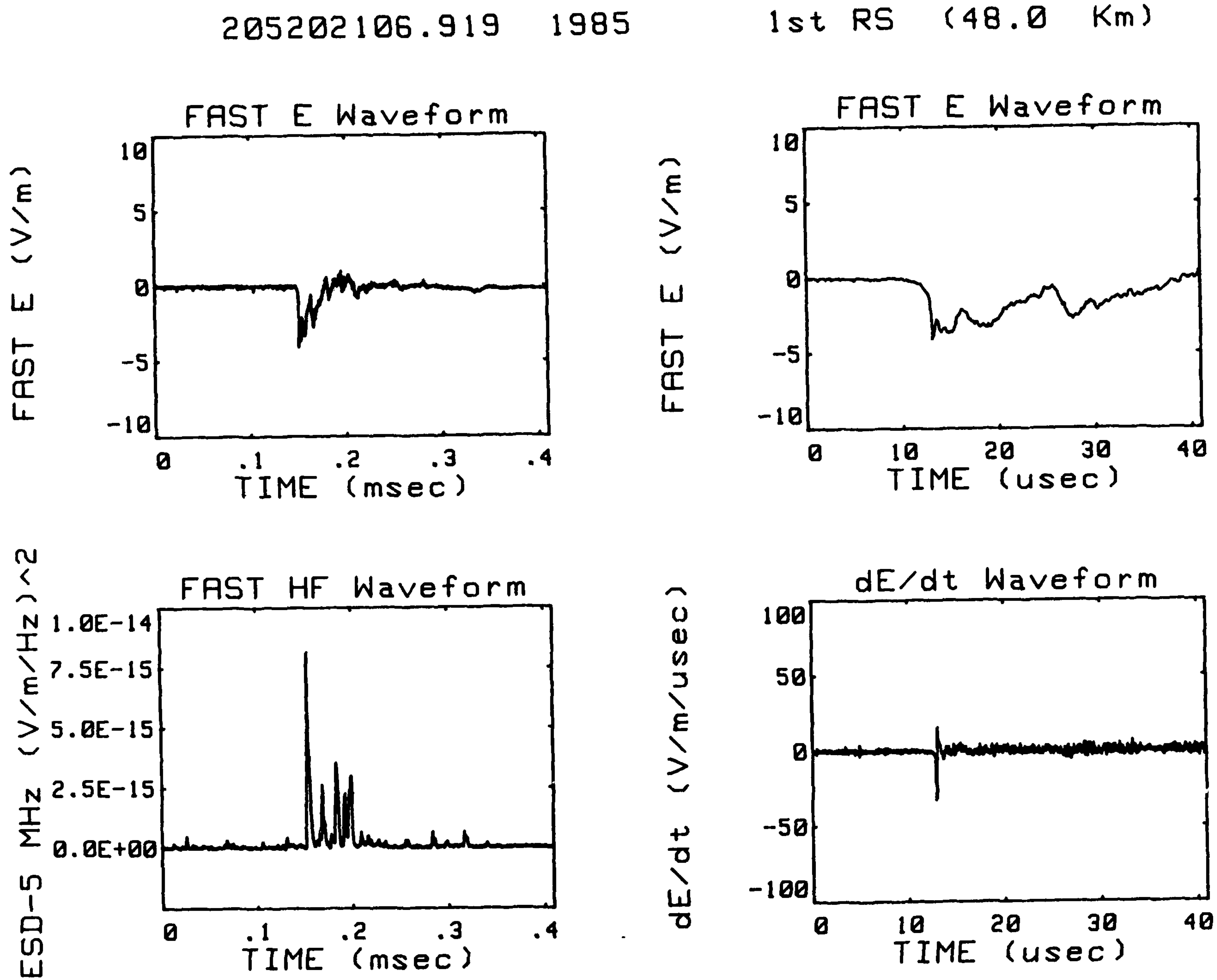
205201959.484 1985 1st RS (47.5 Km)



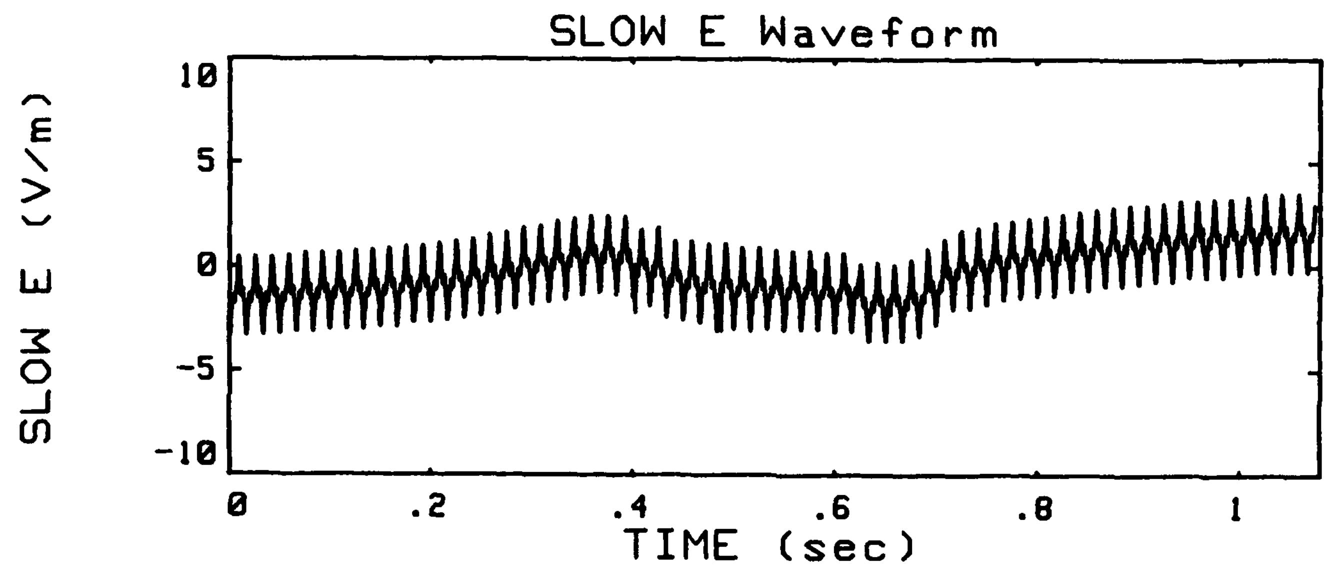
20:19:59.093 24 Jul 1985 (47.5 Km)

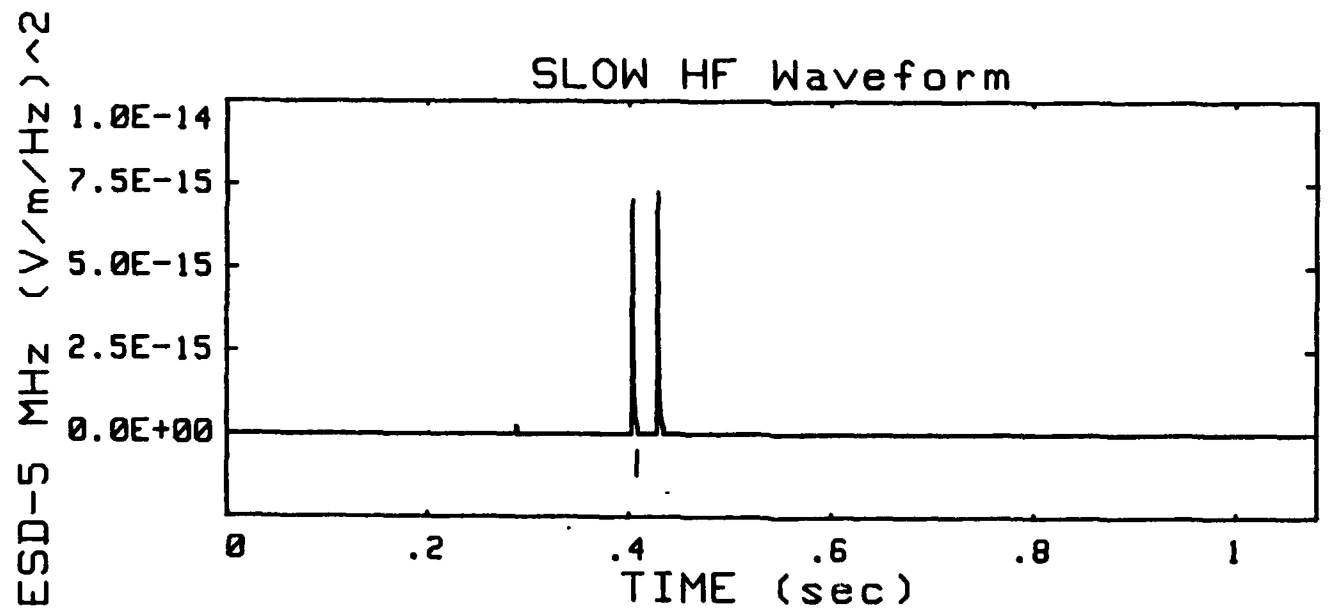


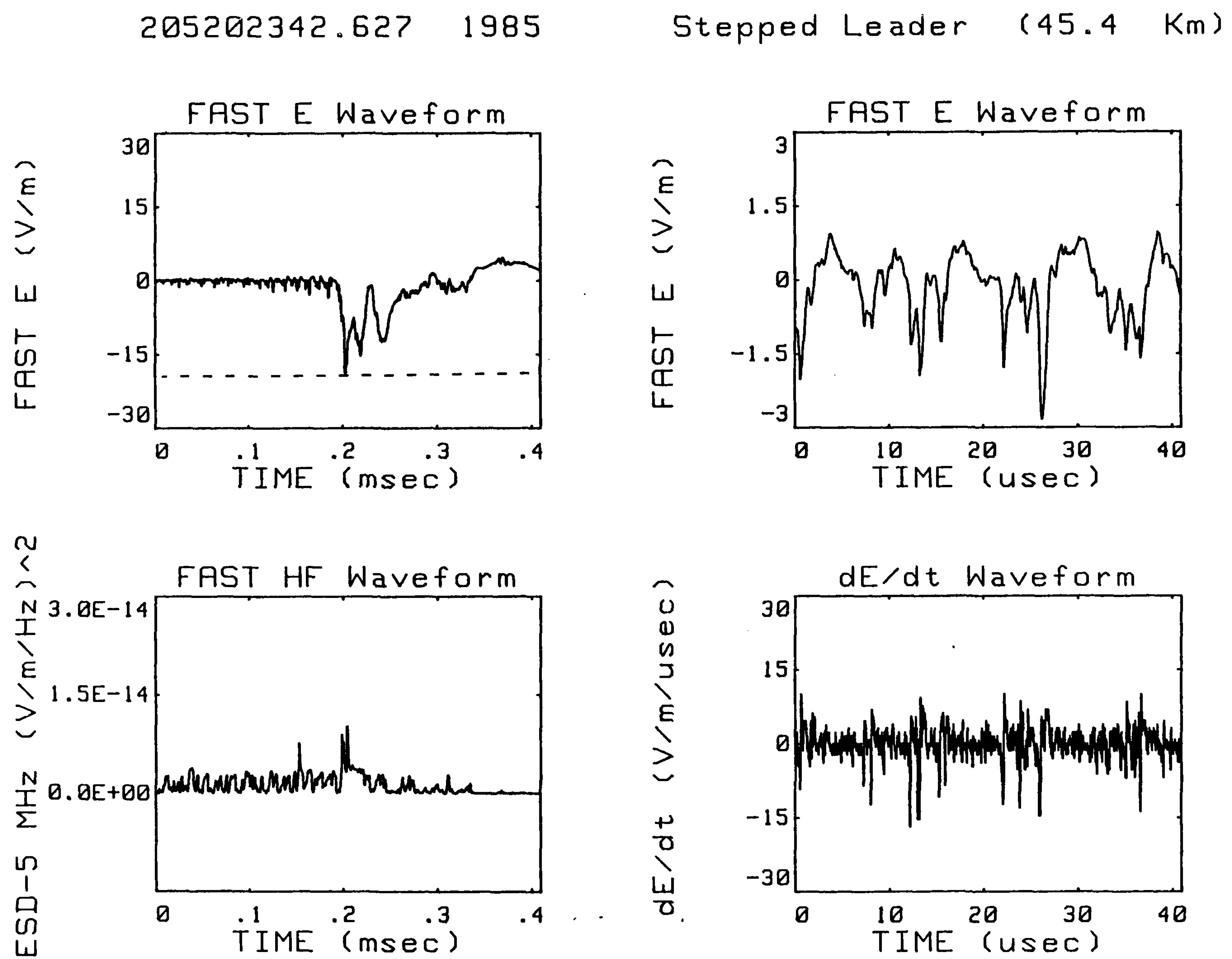



205202106.919 1985
1st RS (48.0 Km)
FAST E Waveform
FAST E (V/m)
TIME (msec)
FAST E Waveform
FAST E (V/m)
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
TIME (usec)

20:21:06.524 24 Jul 1985 (48.0 Km)

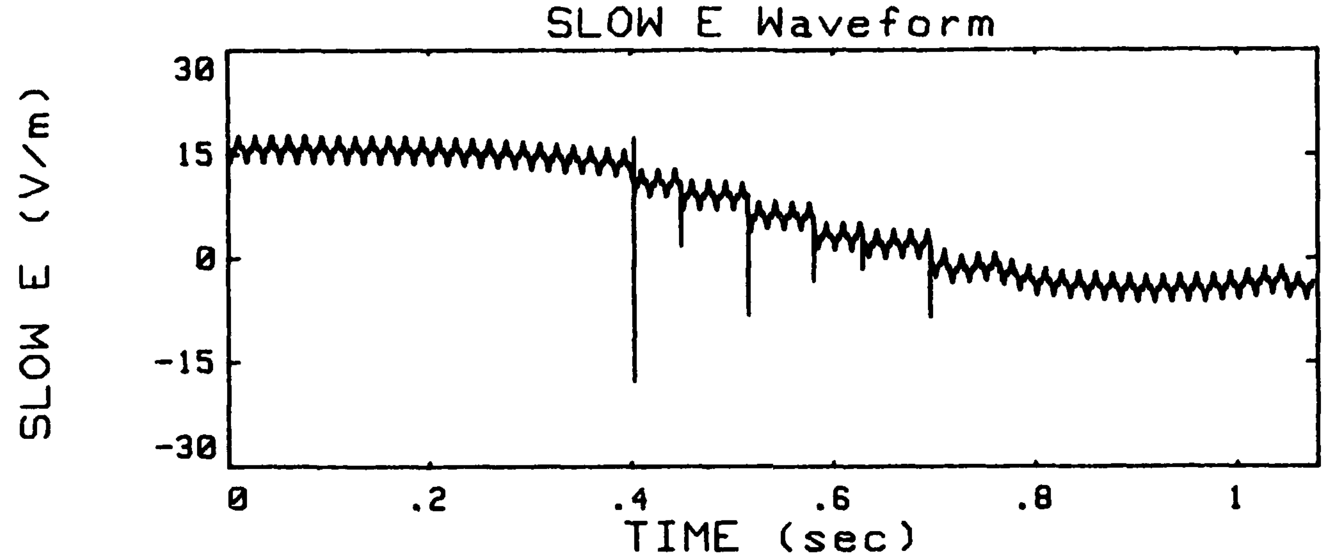


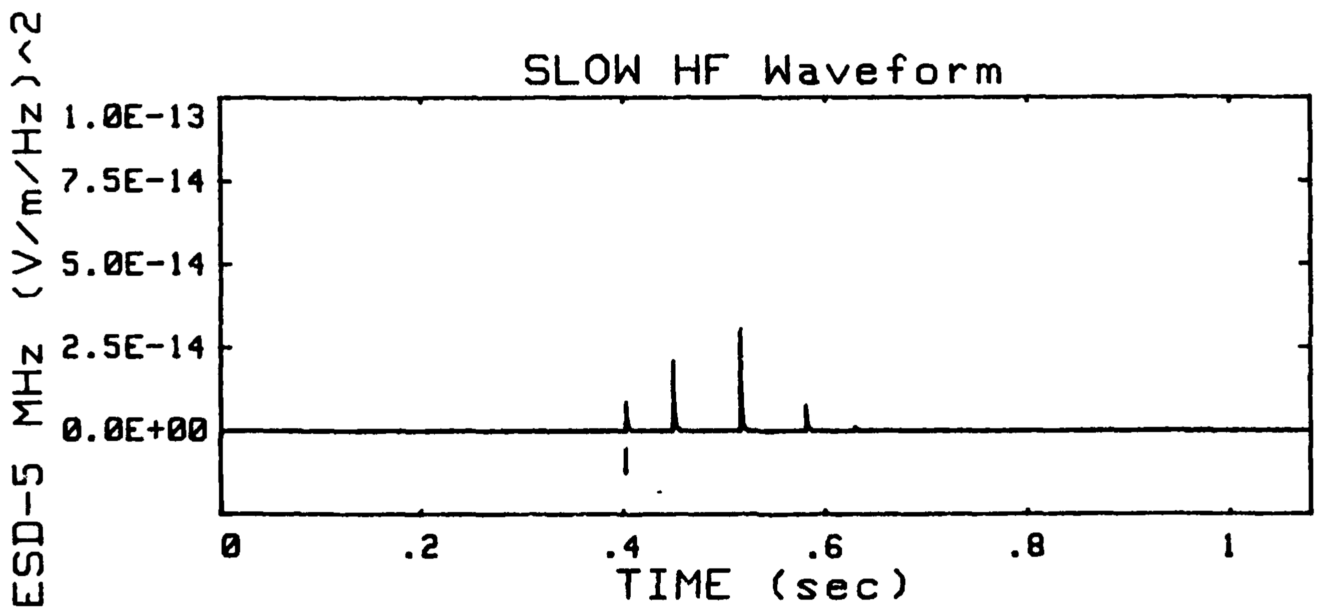




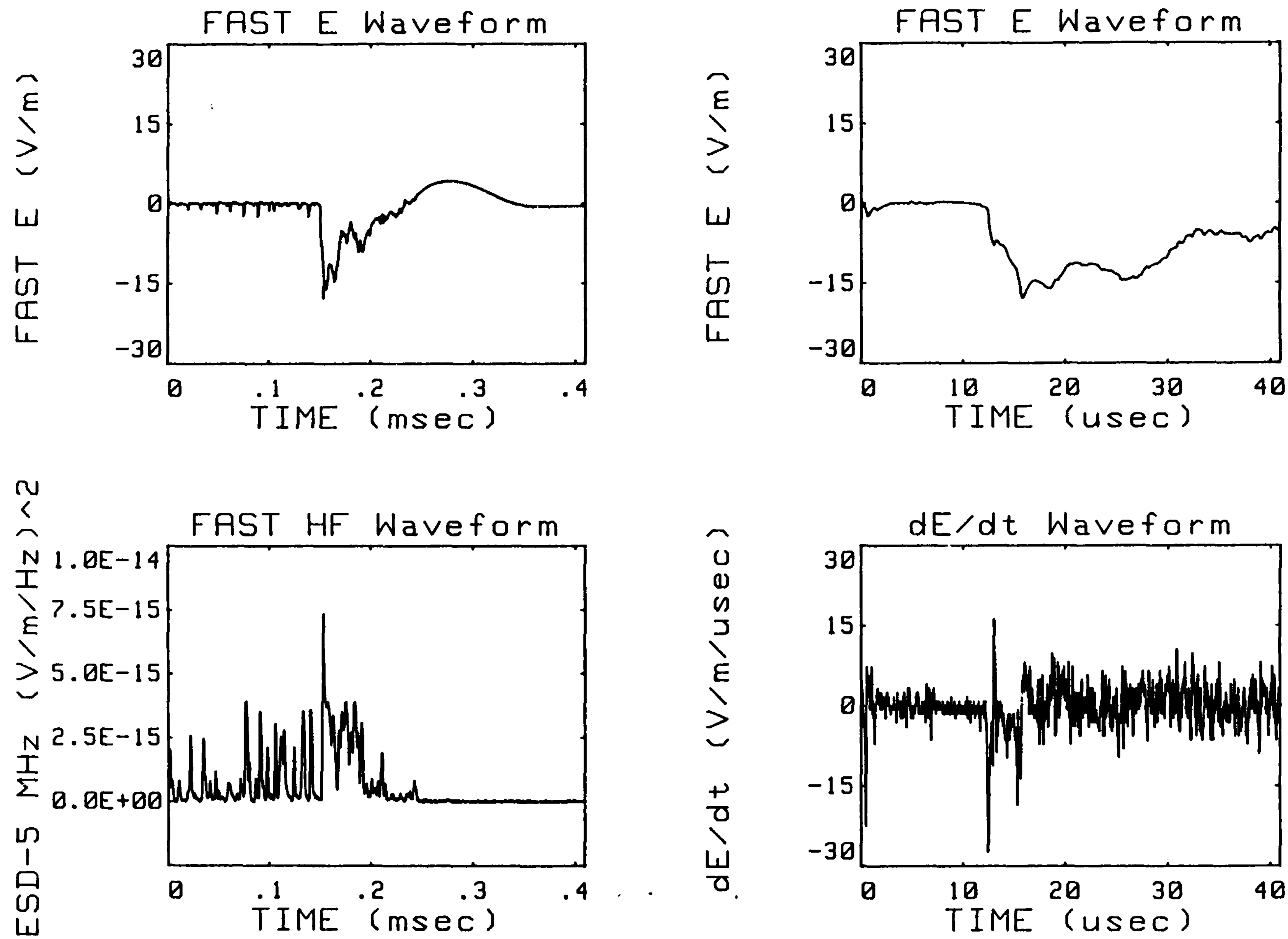
205202342.627 1985
Stepped Leader (45.4 Km)
FAST E Waveform
FAST E (V/m)
30
15
0
-15
-30
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
3
1.5
0
-1.5
-3
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
3.0E-14
1.5E-14
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
30
15
0
-15
-30
0
10
20
30
40
TIME (usec)

20:23:42.237 24 Jul 1985 (45.4 Km)

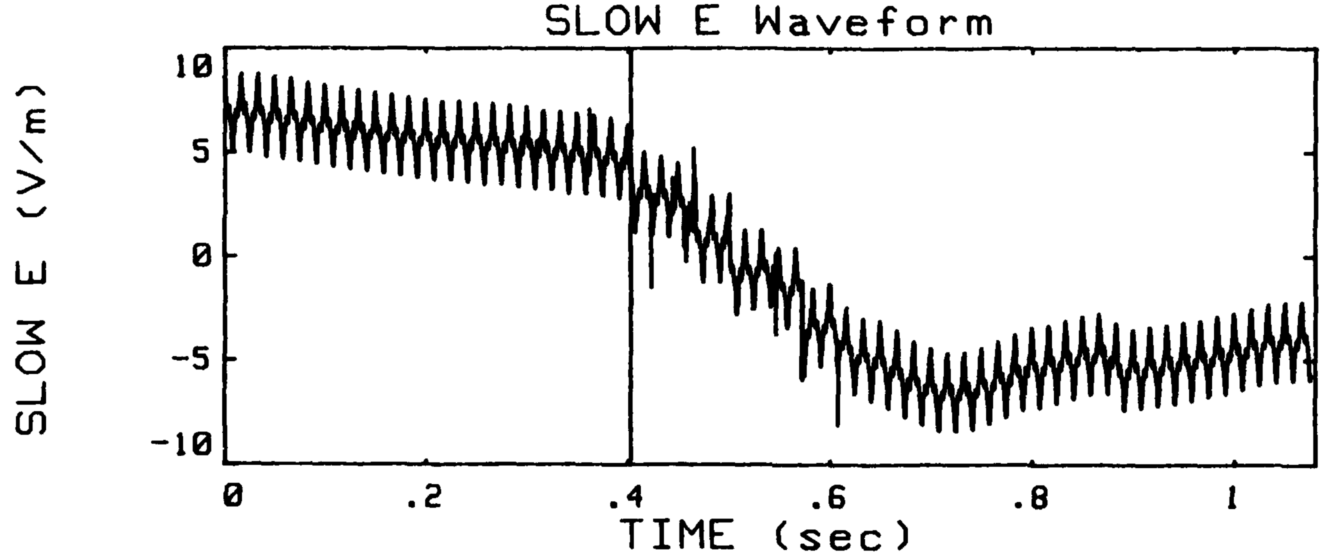


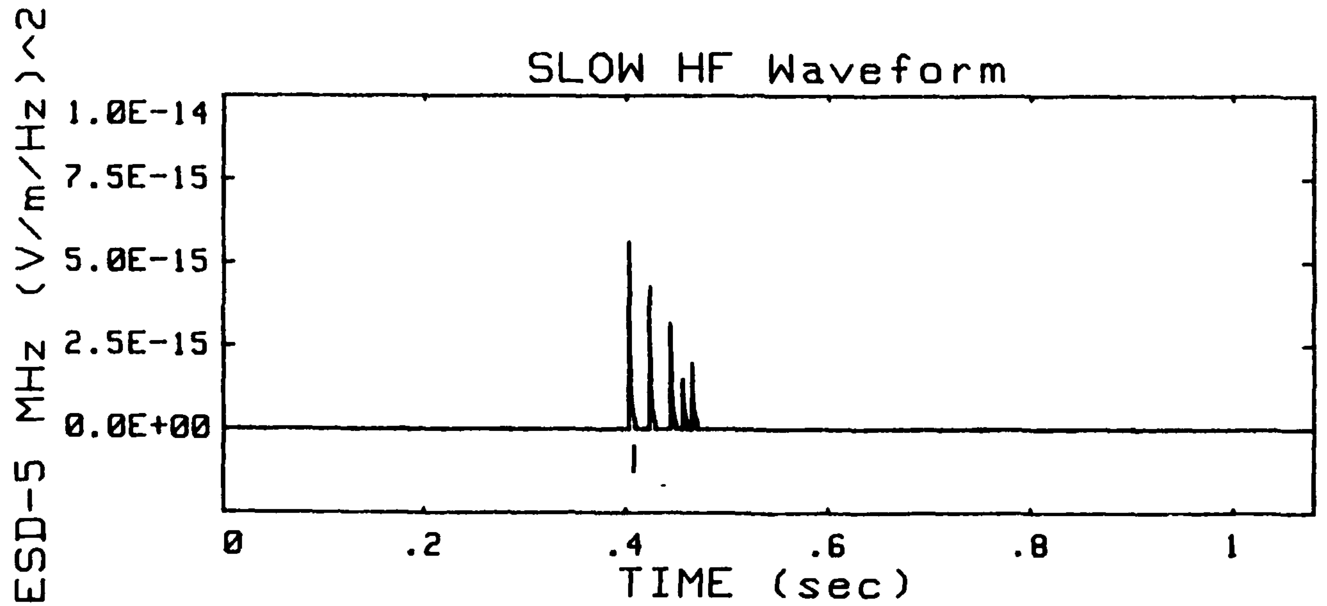


205202354.705 1985 Anomalous #1 RS (47.4 Km)

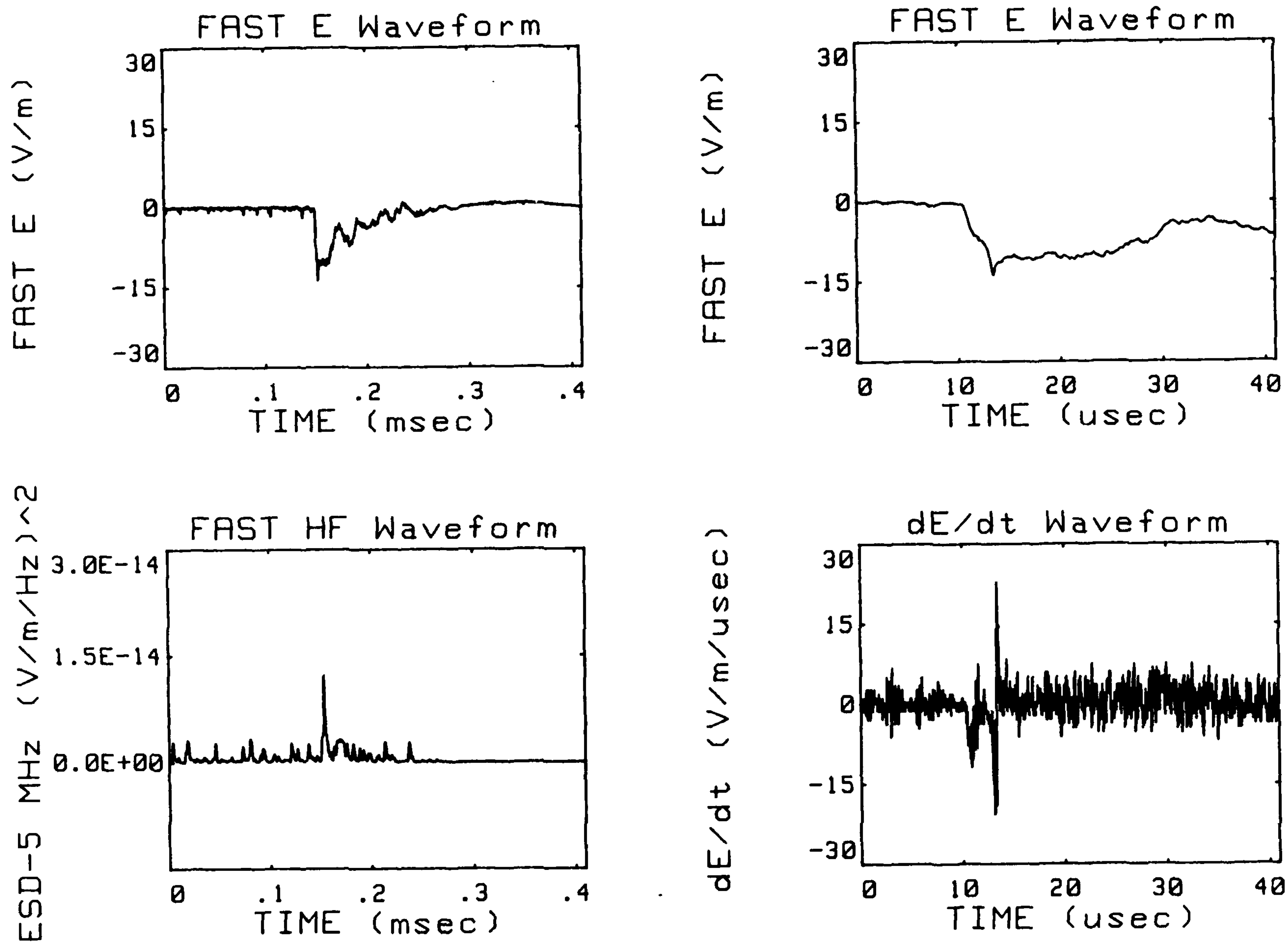


20:23:54.310 24 Jul 1985 (47.4 Km)

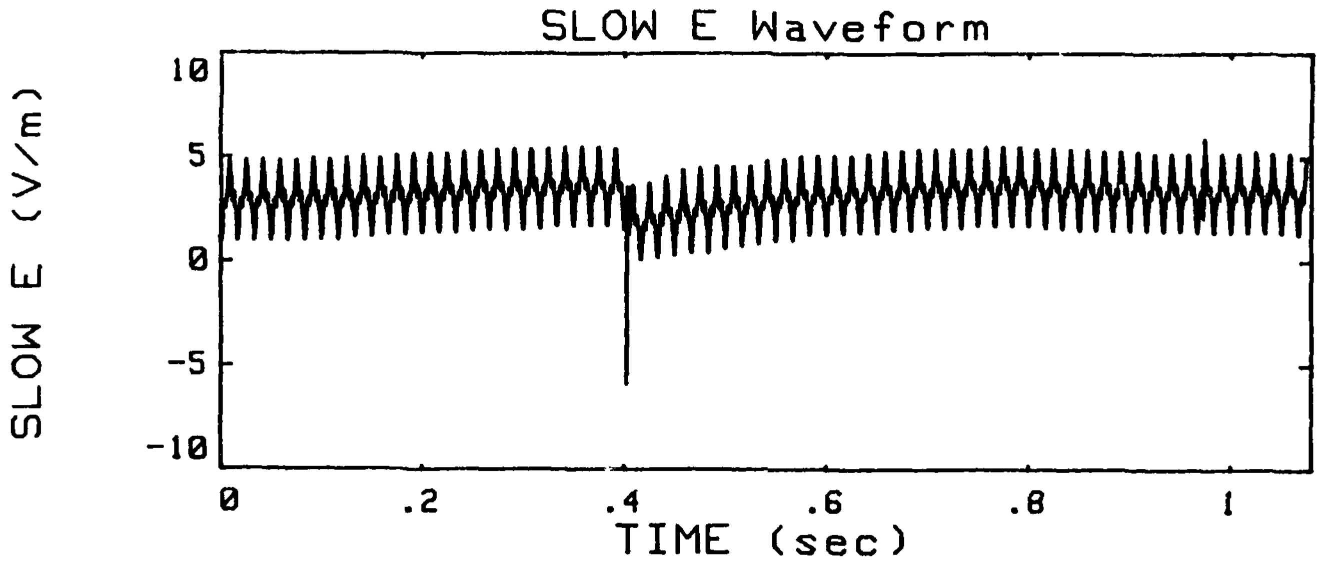


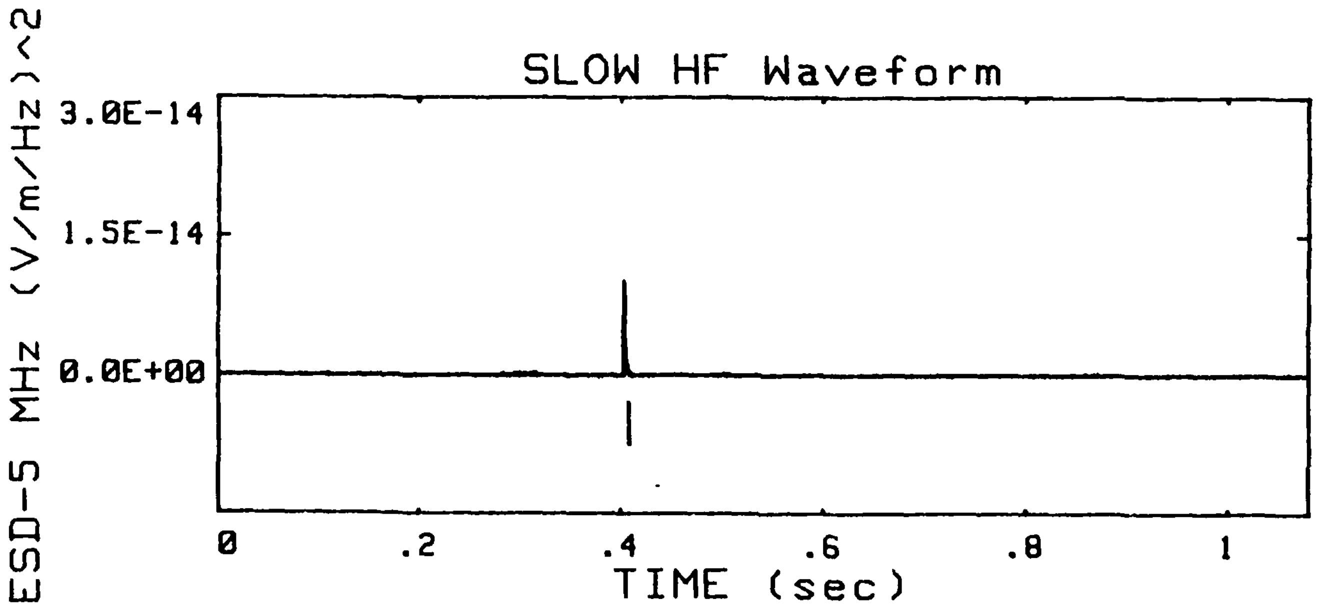


20520241Ø.Ø65 1985 1st RS (47.3 Km)

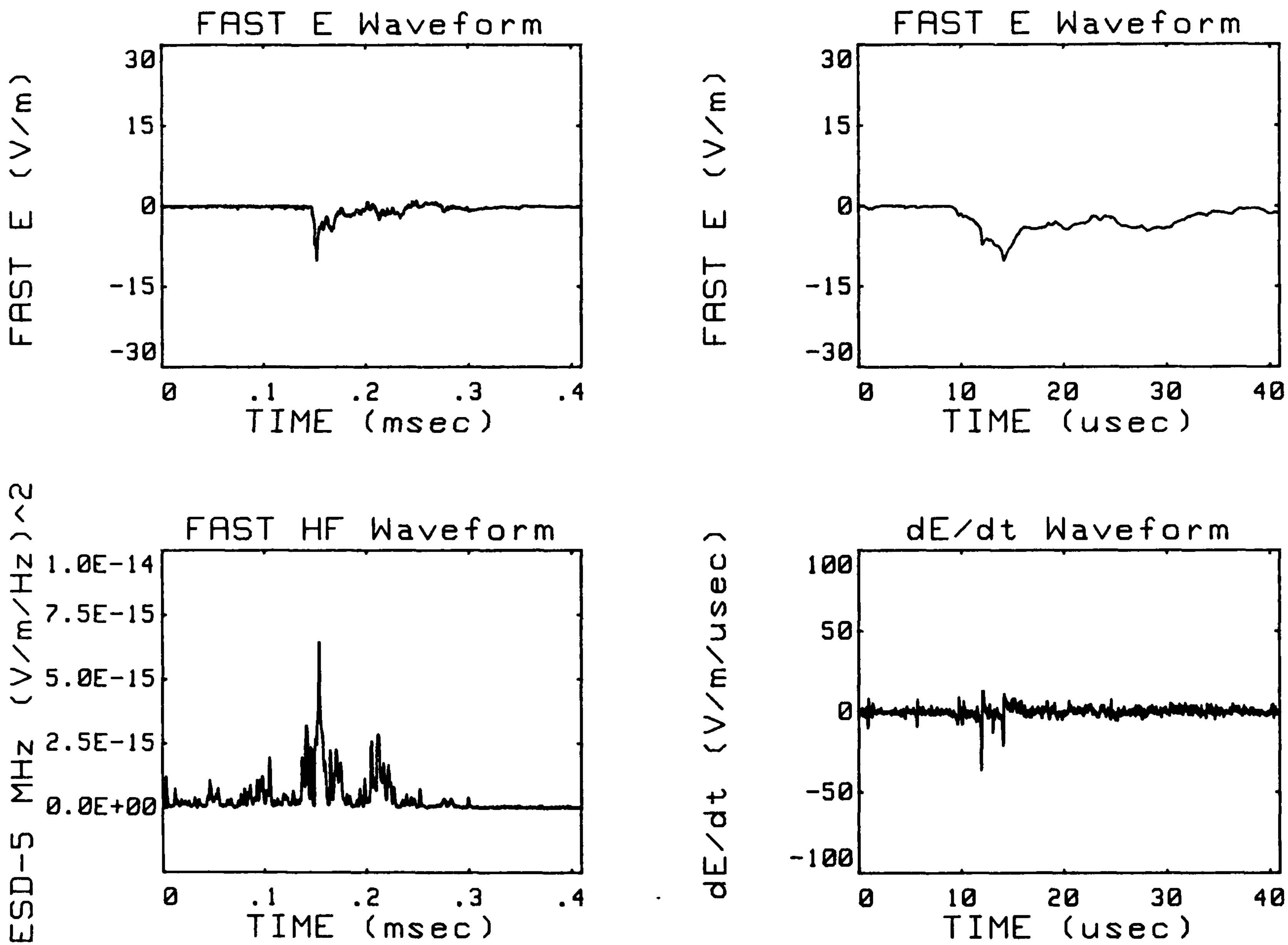


20:24:09.670 24 Jul 1985 (47.3 Km)

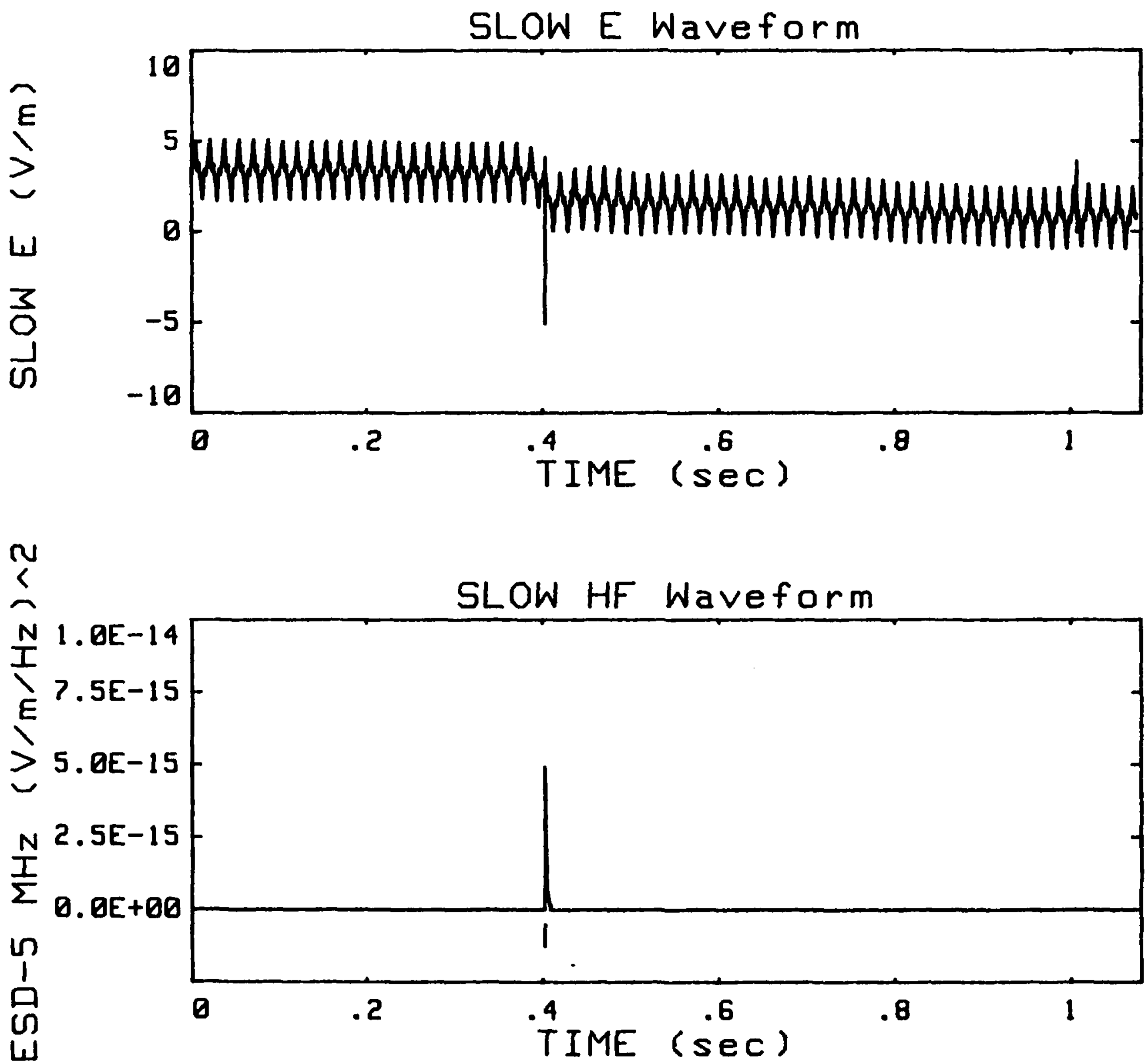




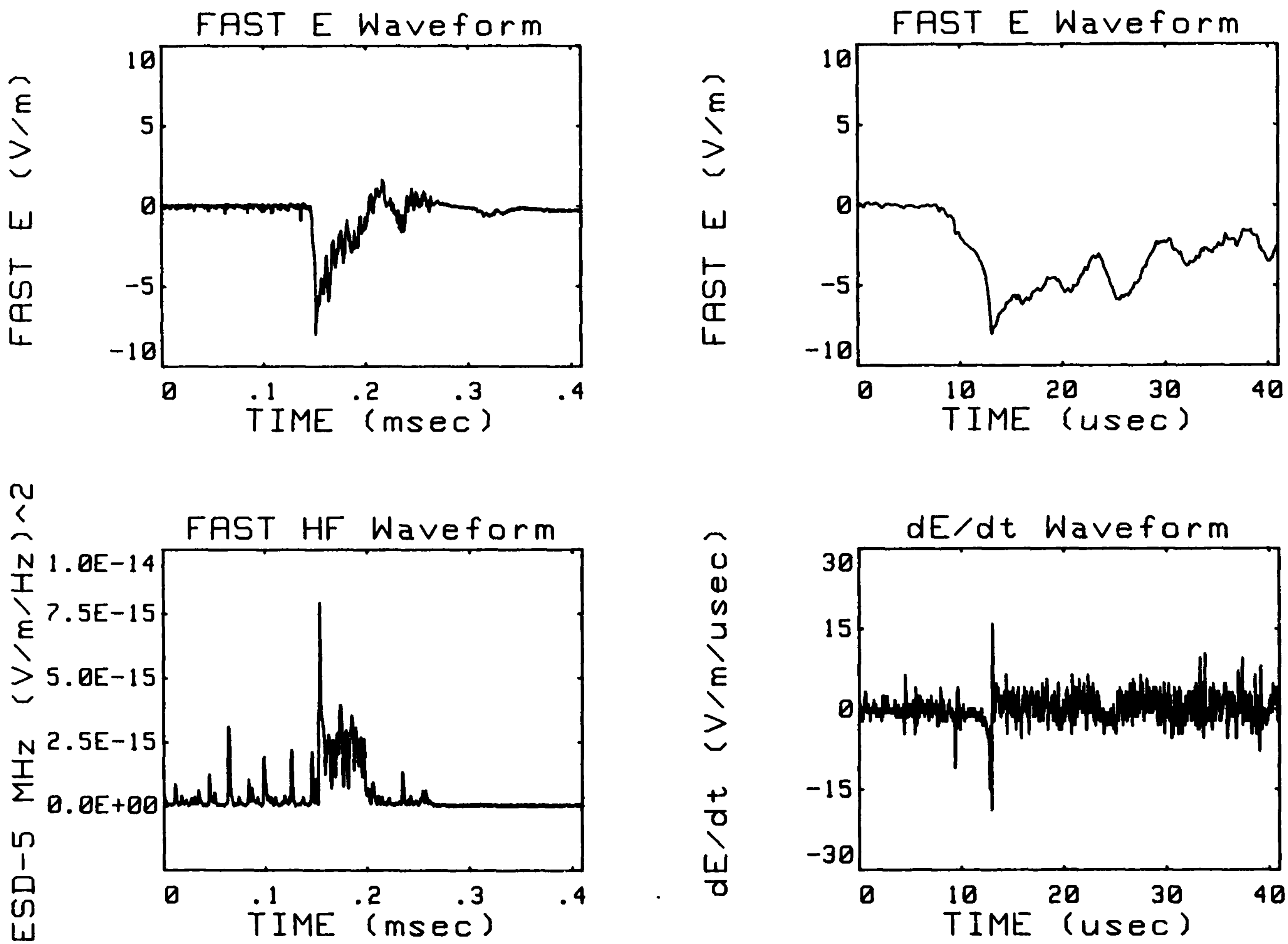
205202446.836 1985 Multiple Gnd RS (43.0 Km)



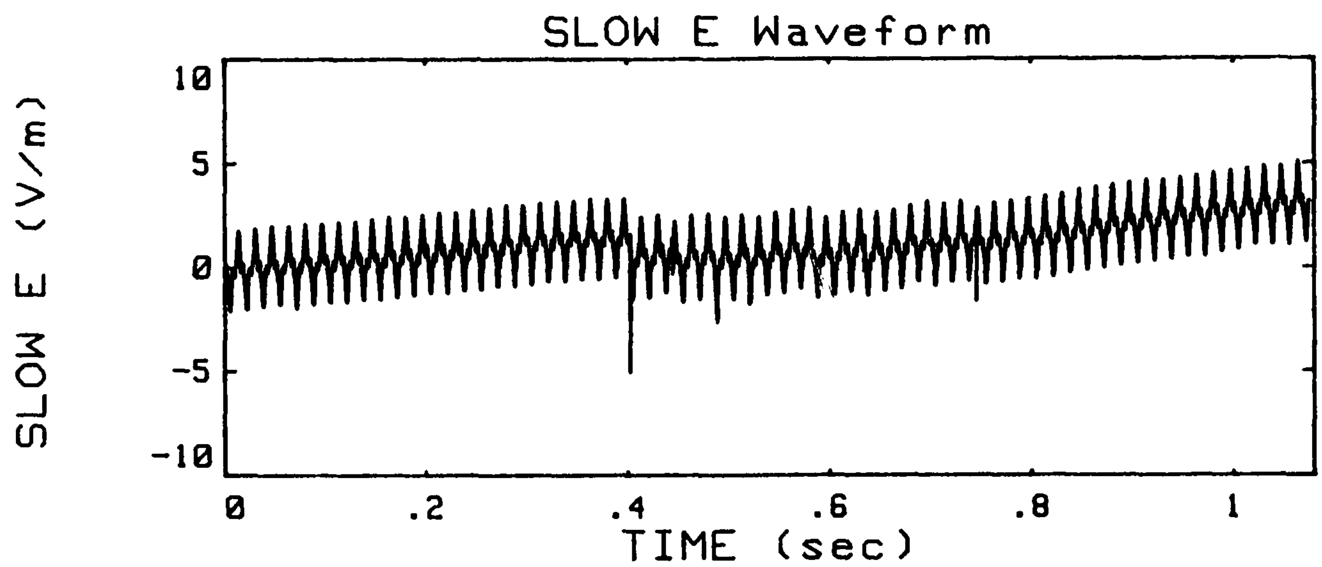
20:24:46.446 24 Jul 1985 (43.0 Km)

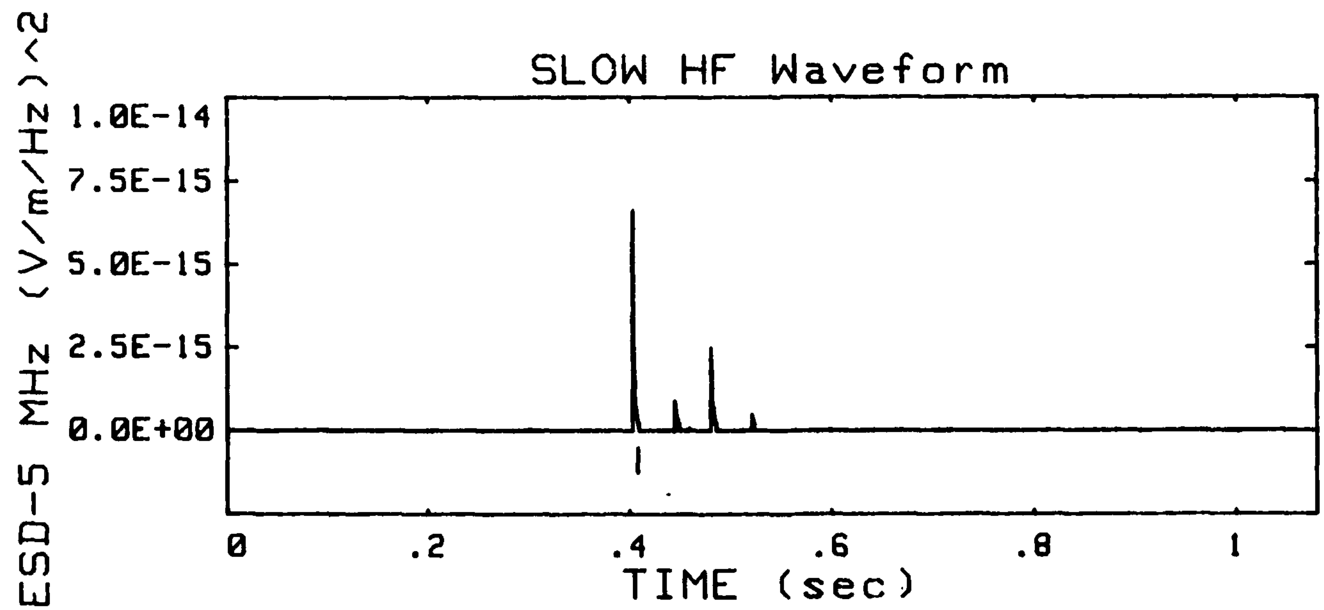


205202523.778 1985 1st RS (46.5 Km)

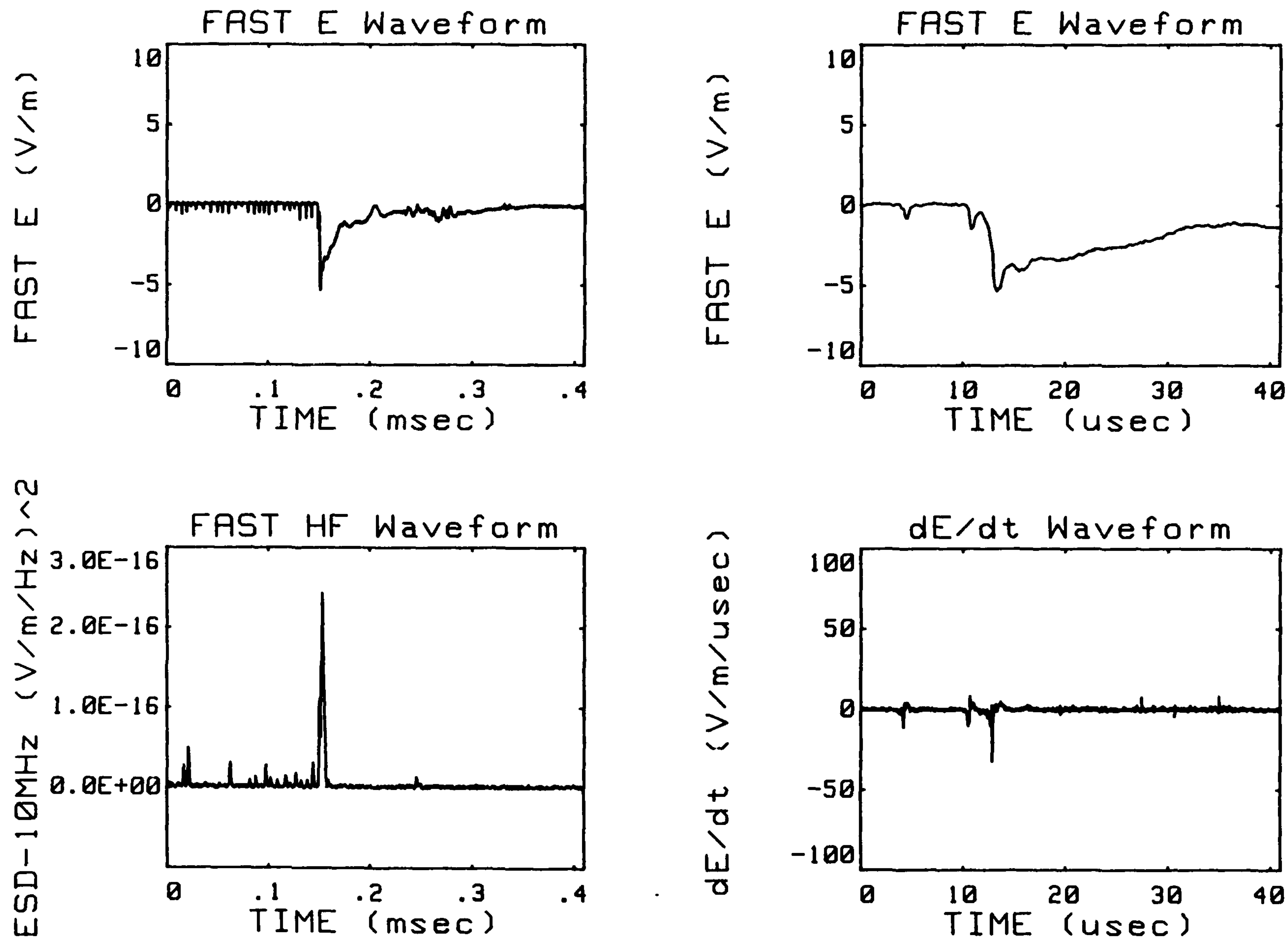


20:25:23.383 24 Jul 1985 (46.5 Km)

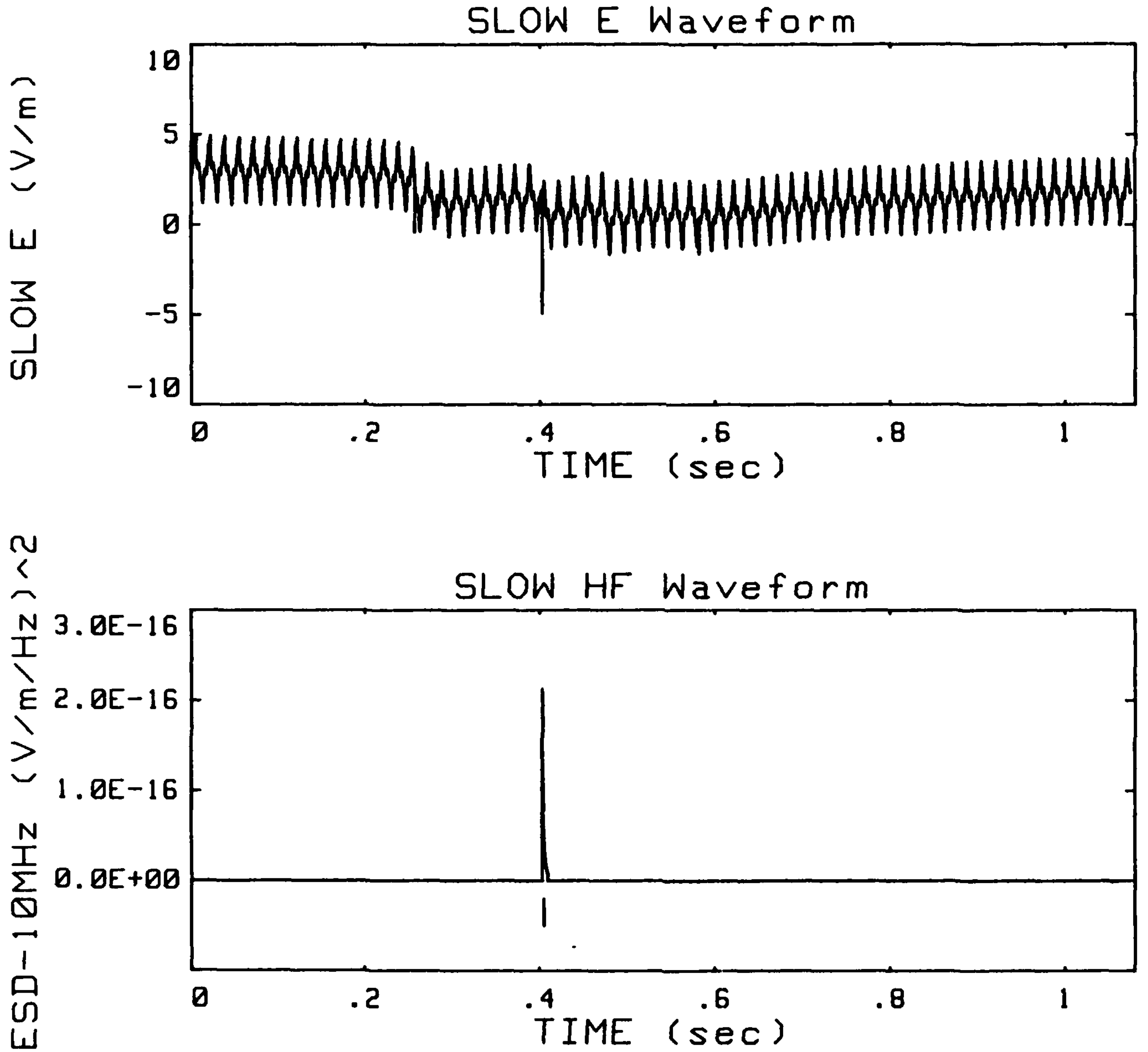




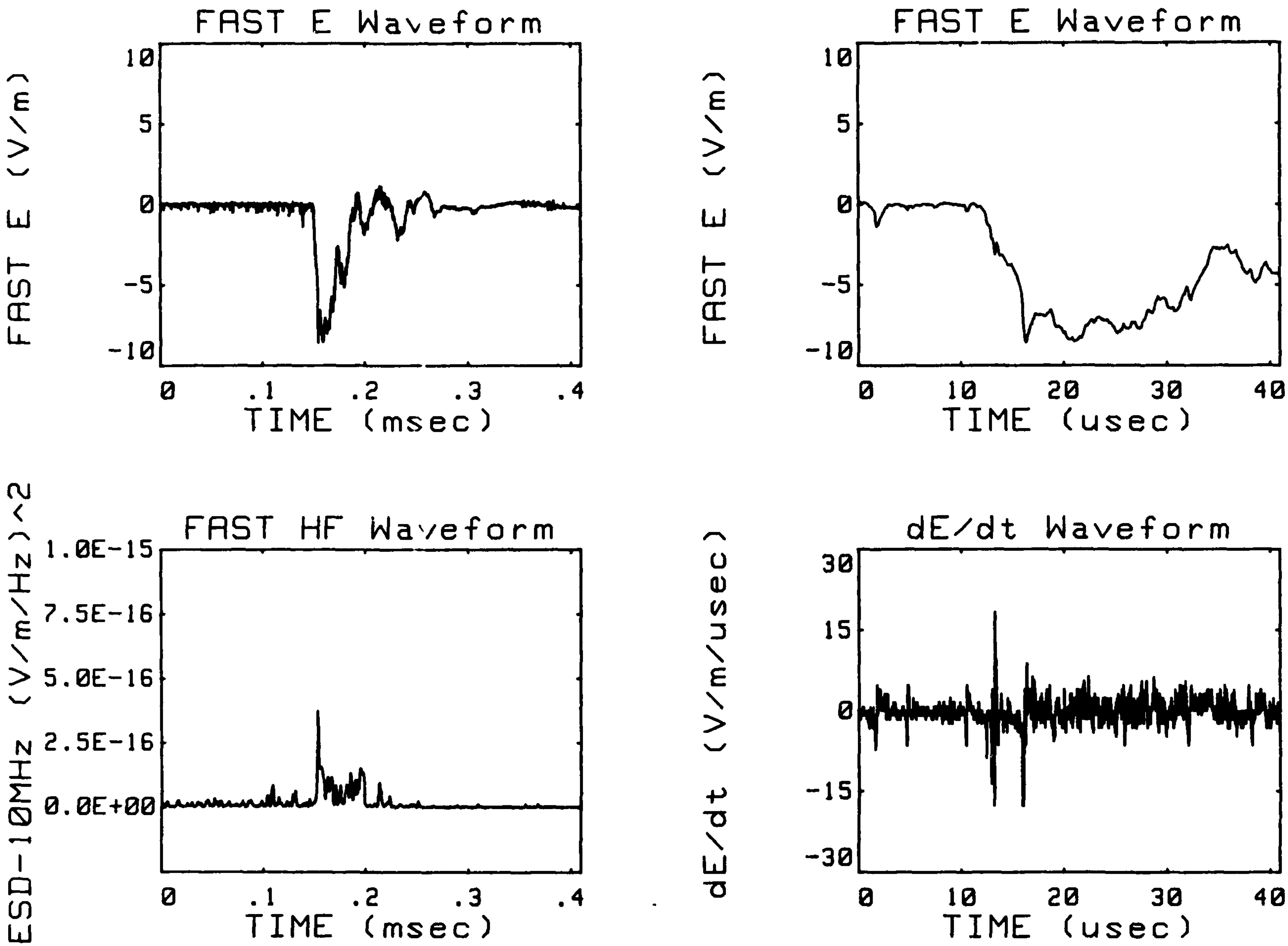
205202812.536 1985 DS Subs RS (46.9 Km)



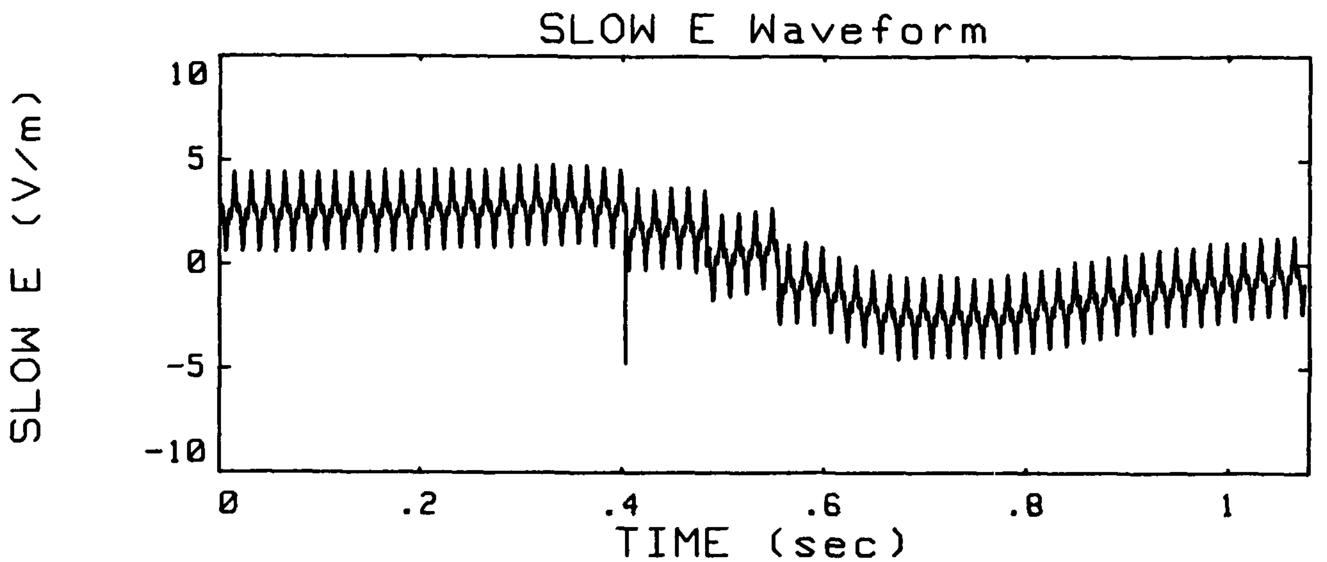
20:28:12.144 24 Jul 1985 (46.9 Km)

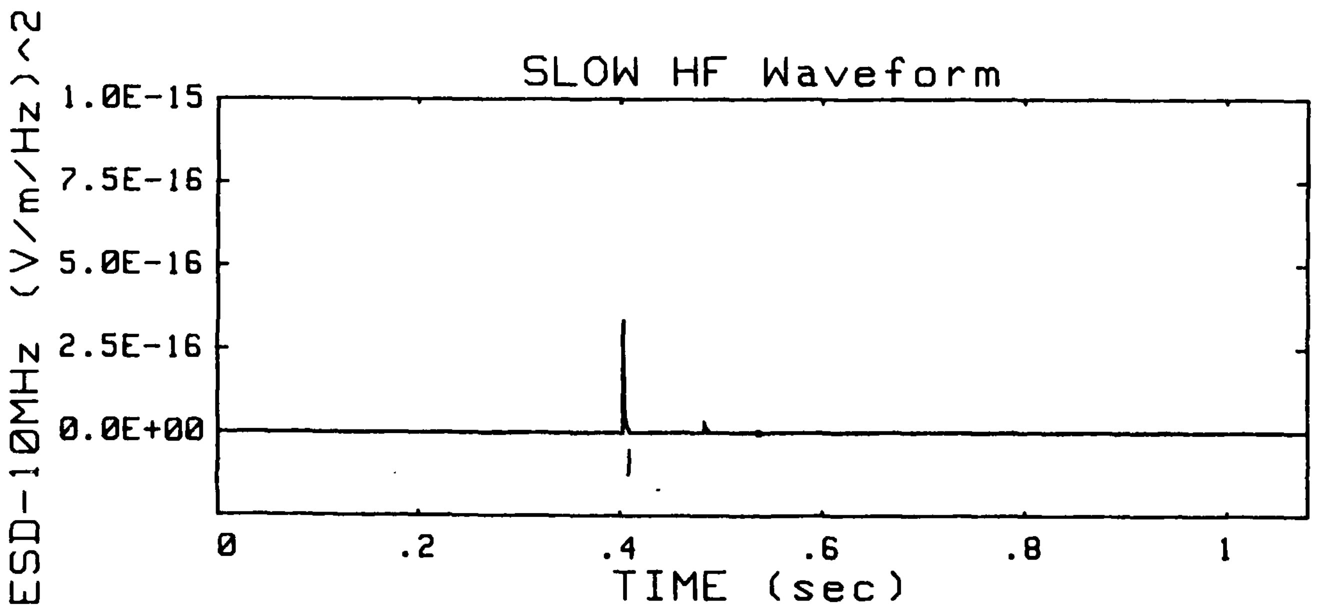


205202934.739 1985 1st RS (47.1 Km)

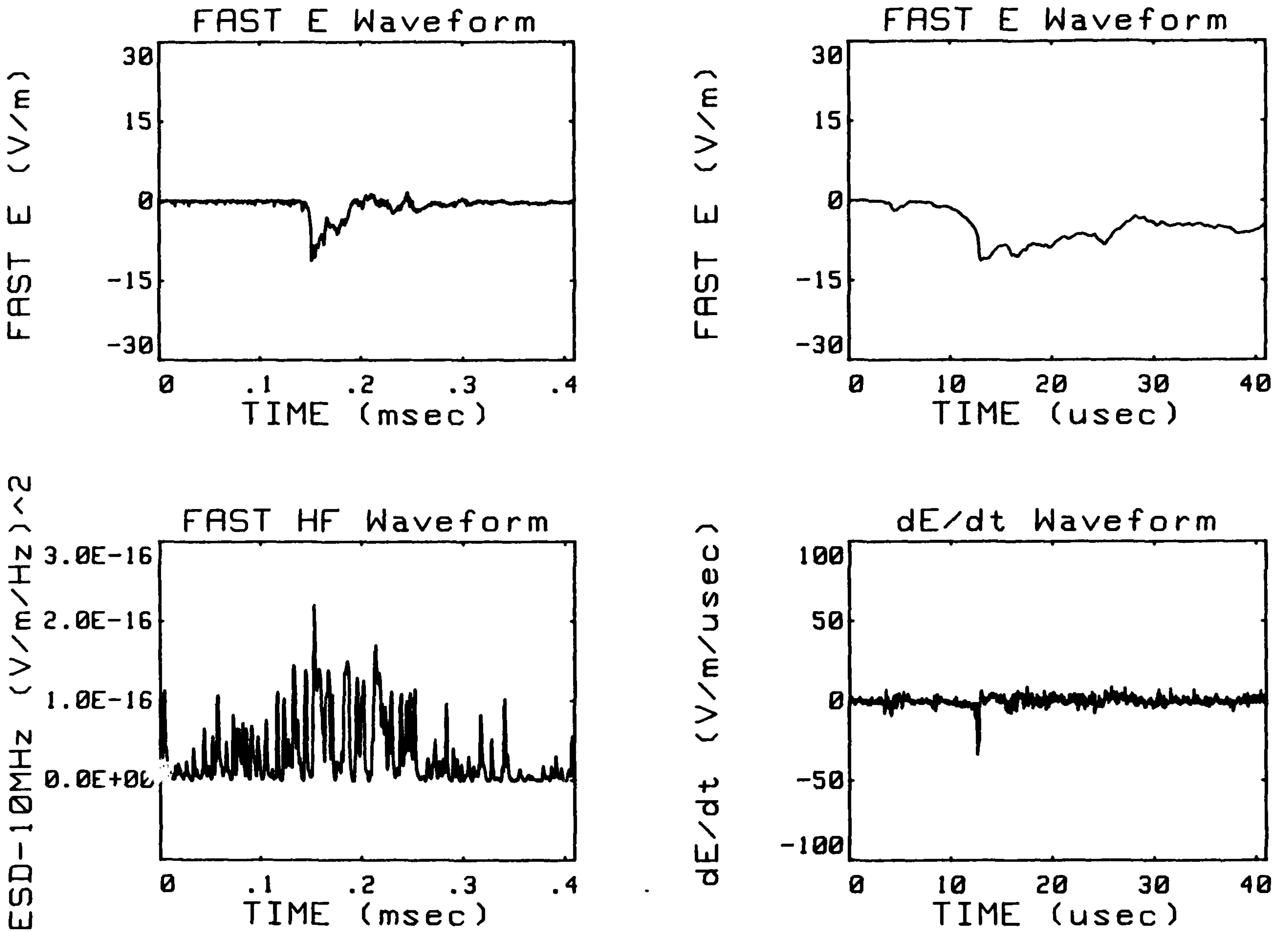


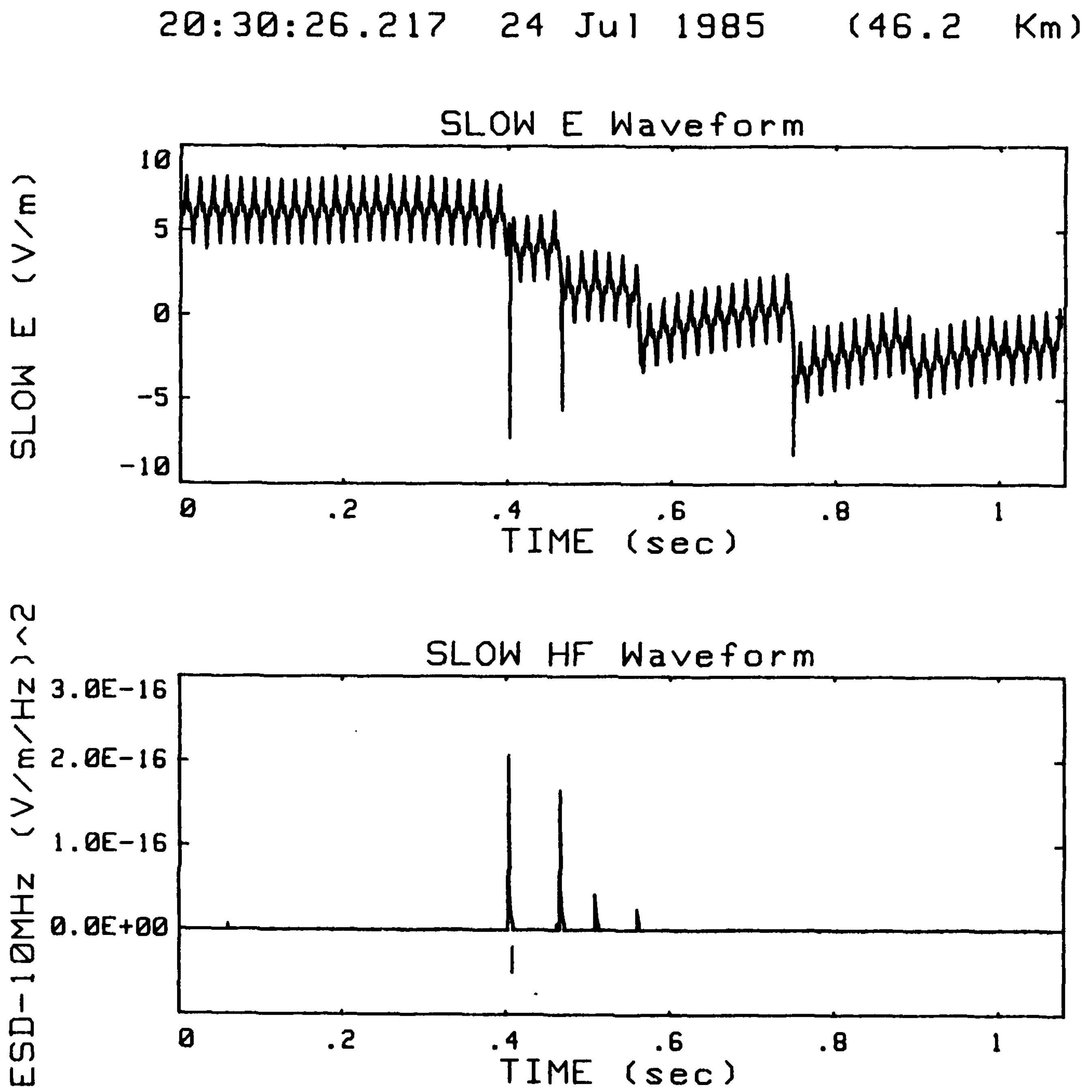
20:29:34.343 24 Jul 1985 (47.1 Km)





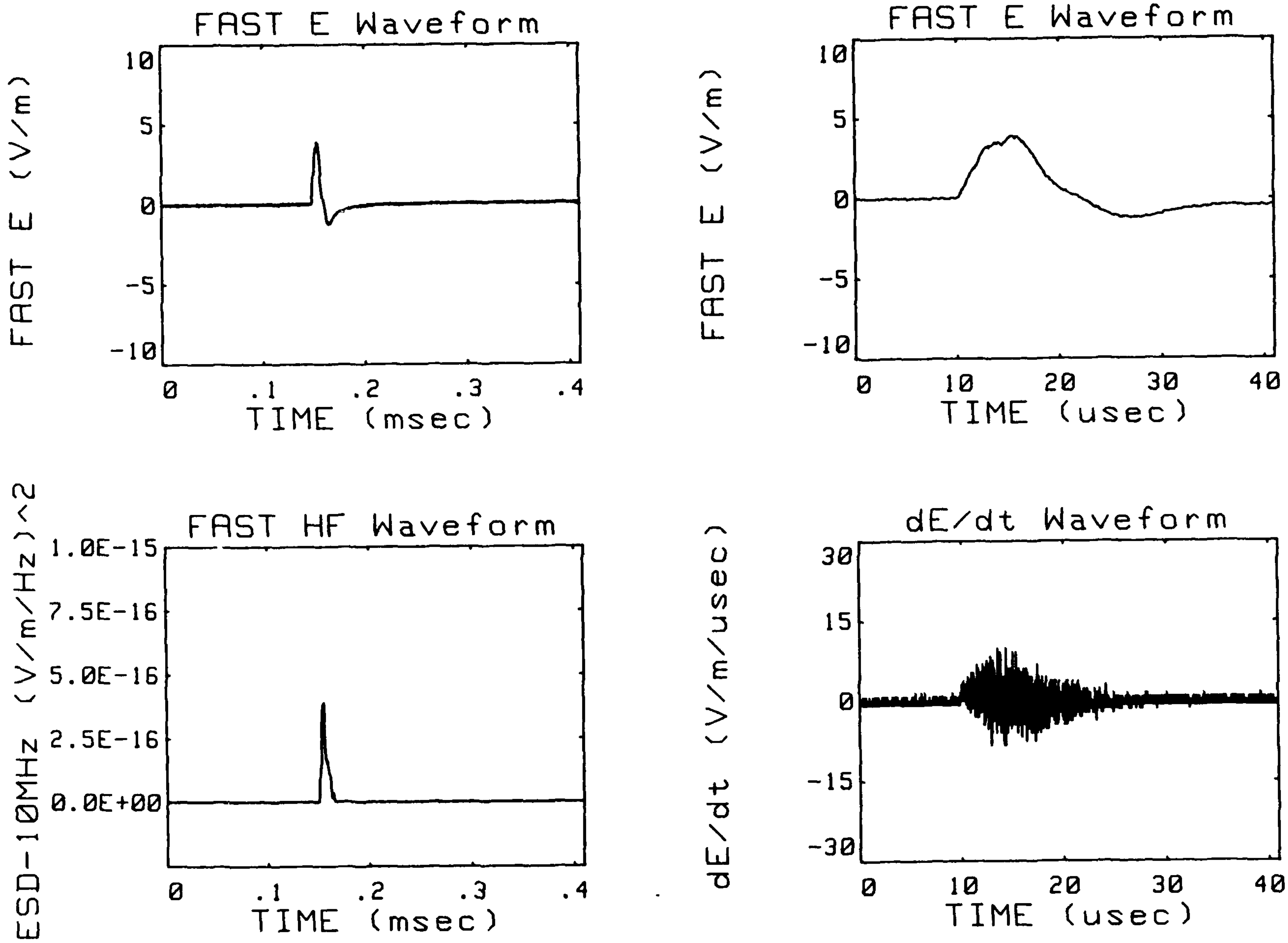
205203026.612 1985 1st RS (46.2 Km)

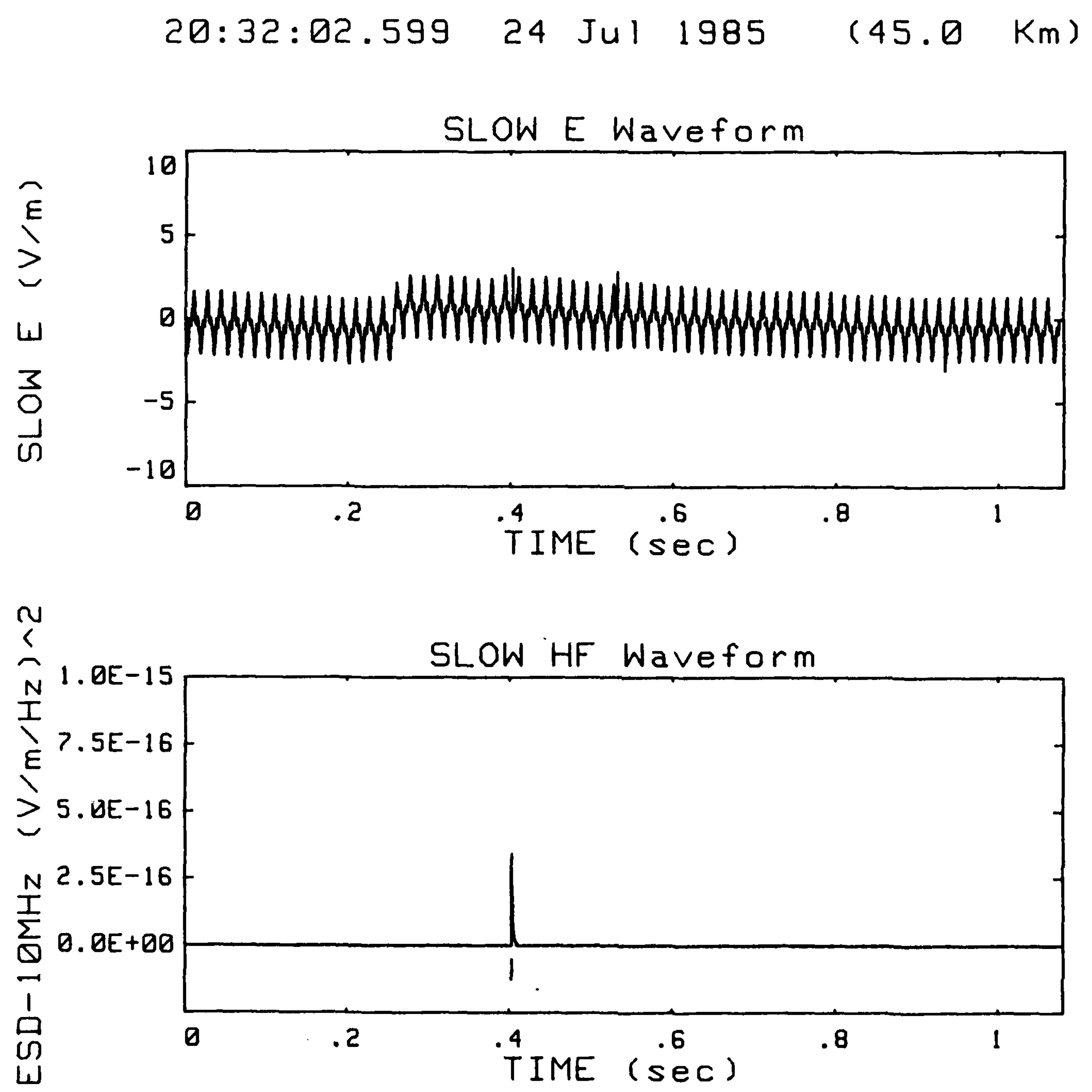




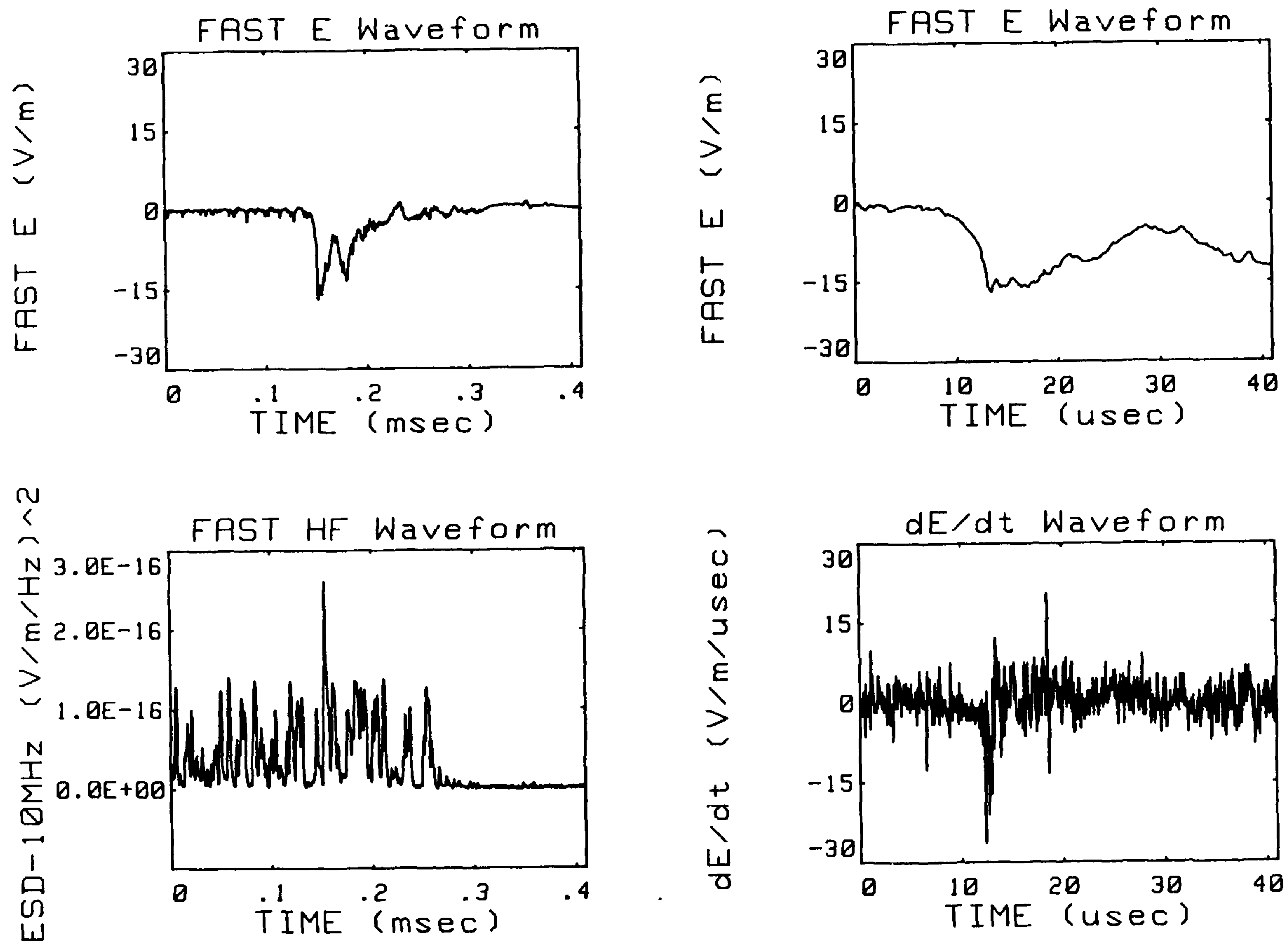
20:30:26.217 24 Jul 1985 (46.2 Km)
SLOW E Waveform
SLOW E (V/m)
10
5
0
-5
-10
0
.2
.4
.6
.8
1
TIME (sec)
SLOW HF Waveform
ESD-10MHz (V/m/Hz)^2
3.0E-16
2.0E-16
1.0E-16
0.0E+00
0
.2
.4
.6
.8
1
TIME (sec)

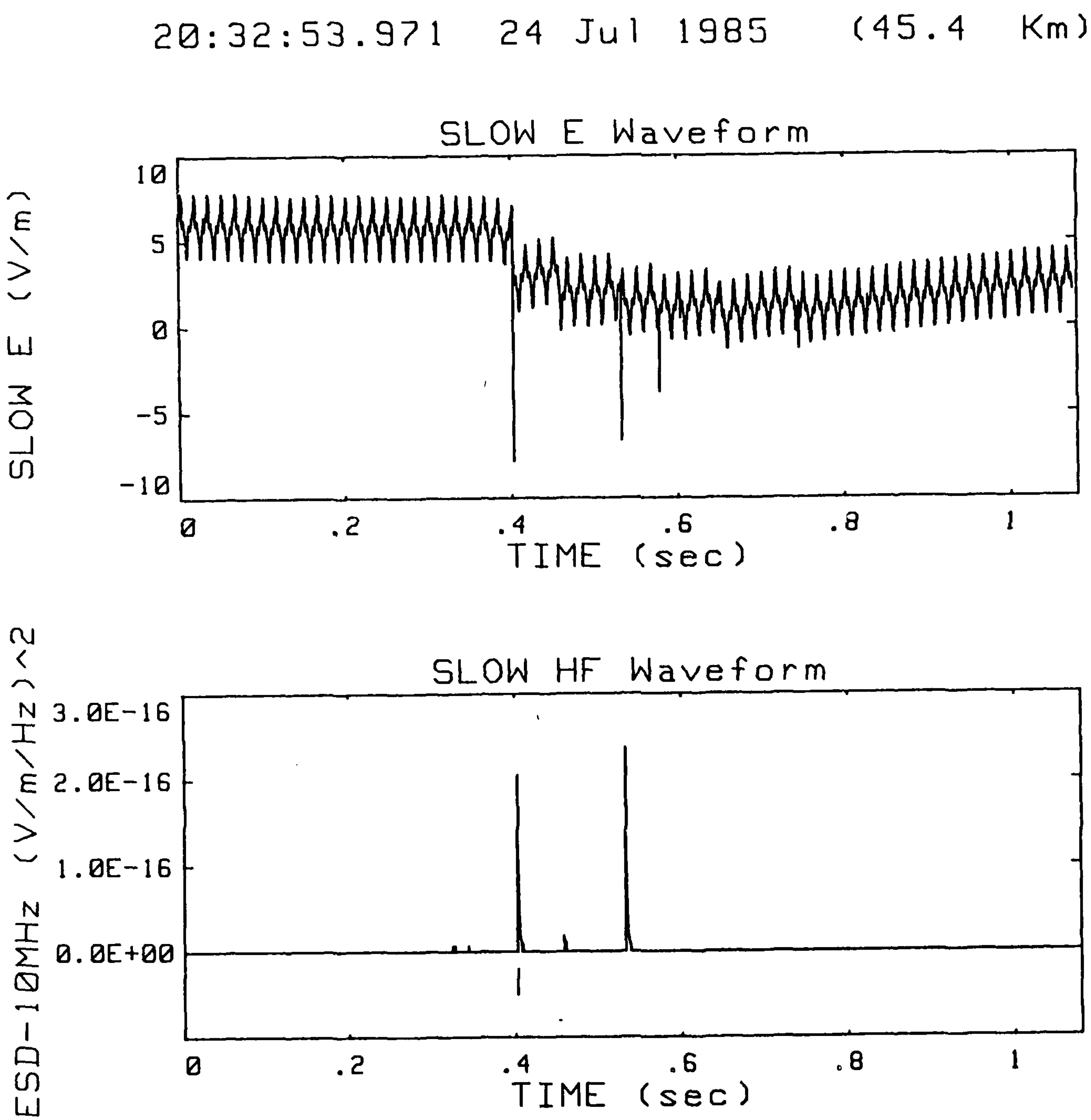
205203202.989 1985 NPBP (45.0 Km)



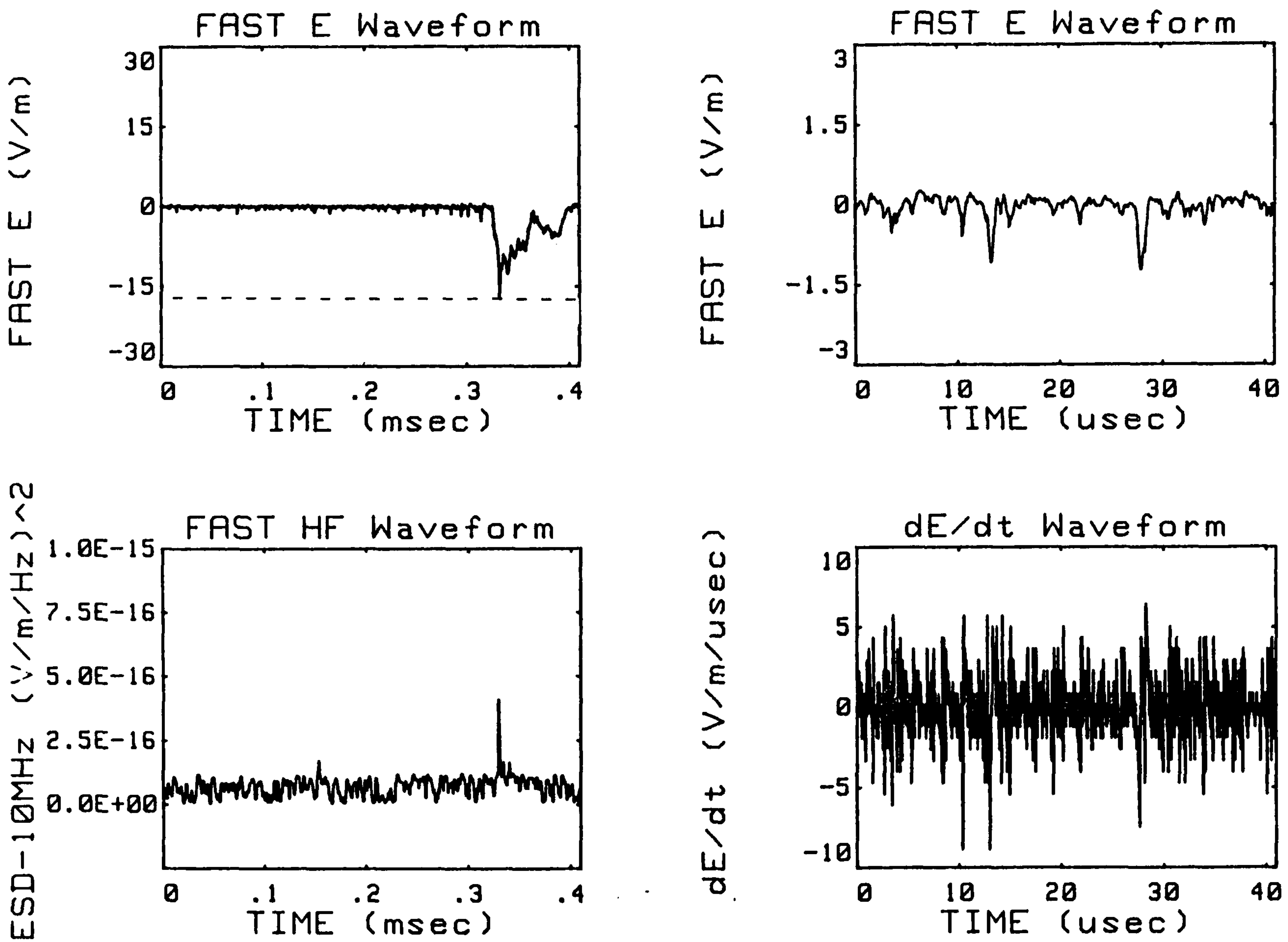

20:32:02.599 24 Jul 1985 (45.0 Km)
SLOW E Waveform
SLOW E (V/m)
10
5
0
-5
-10
0
.2
.4
.6
.8
1
TIME (sec)
SLOW HF Waveform
ESD-10MHz (V/m/Hz)^2
1.0E-15
7.5E-16
5.0E-16
2.5E-16
0.0E+00
0
.2
.4
.6
.8
1
TIME (sec)

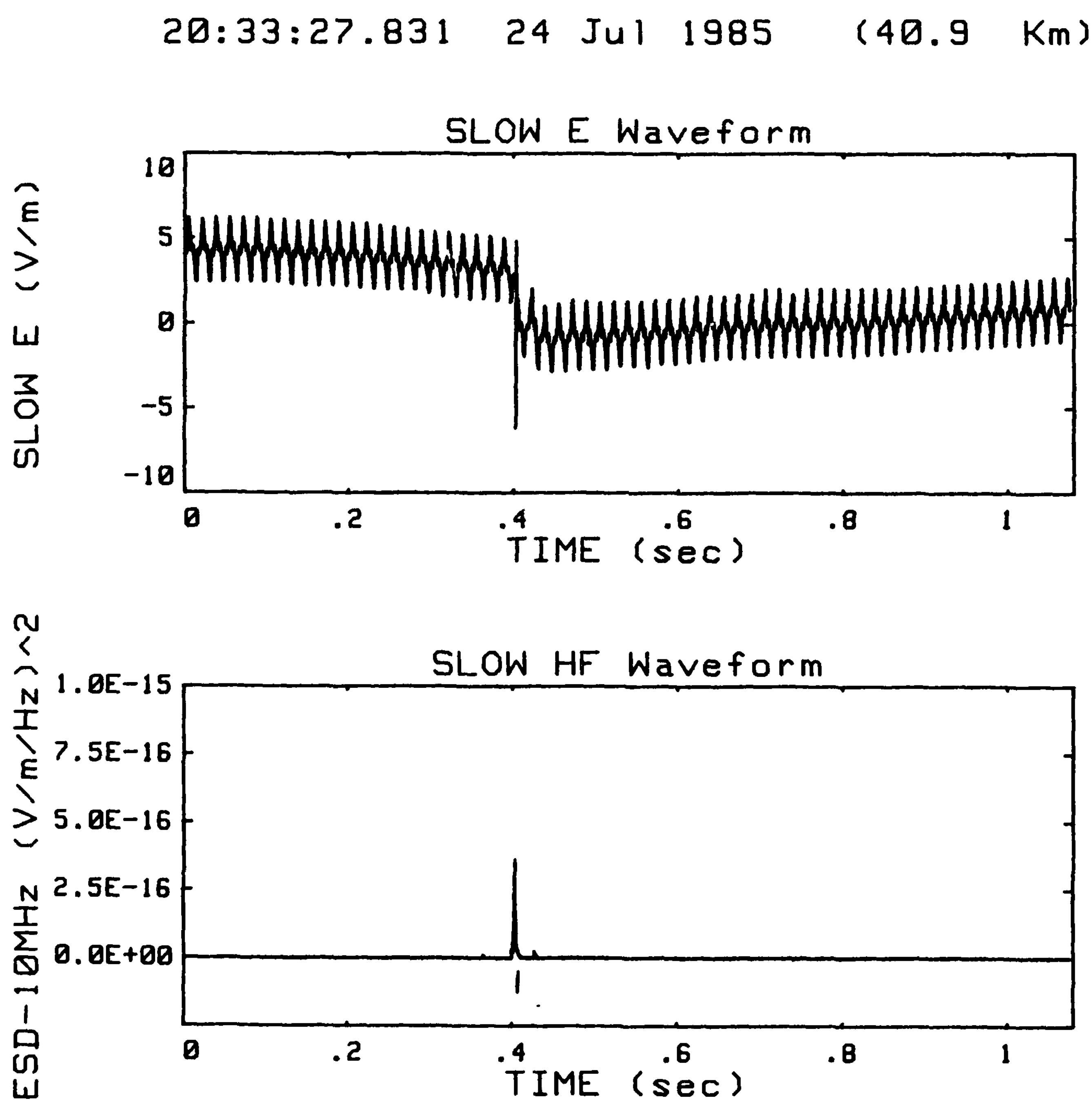
205203254.361 1985 1st RS (45.4 Km)



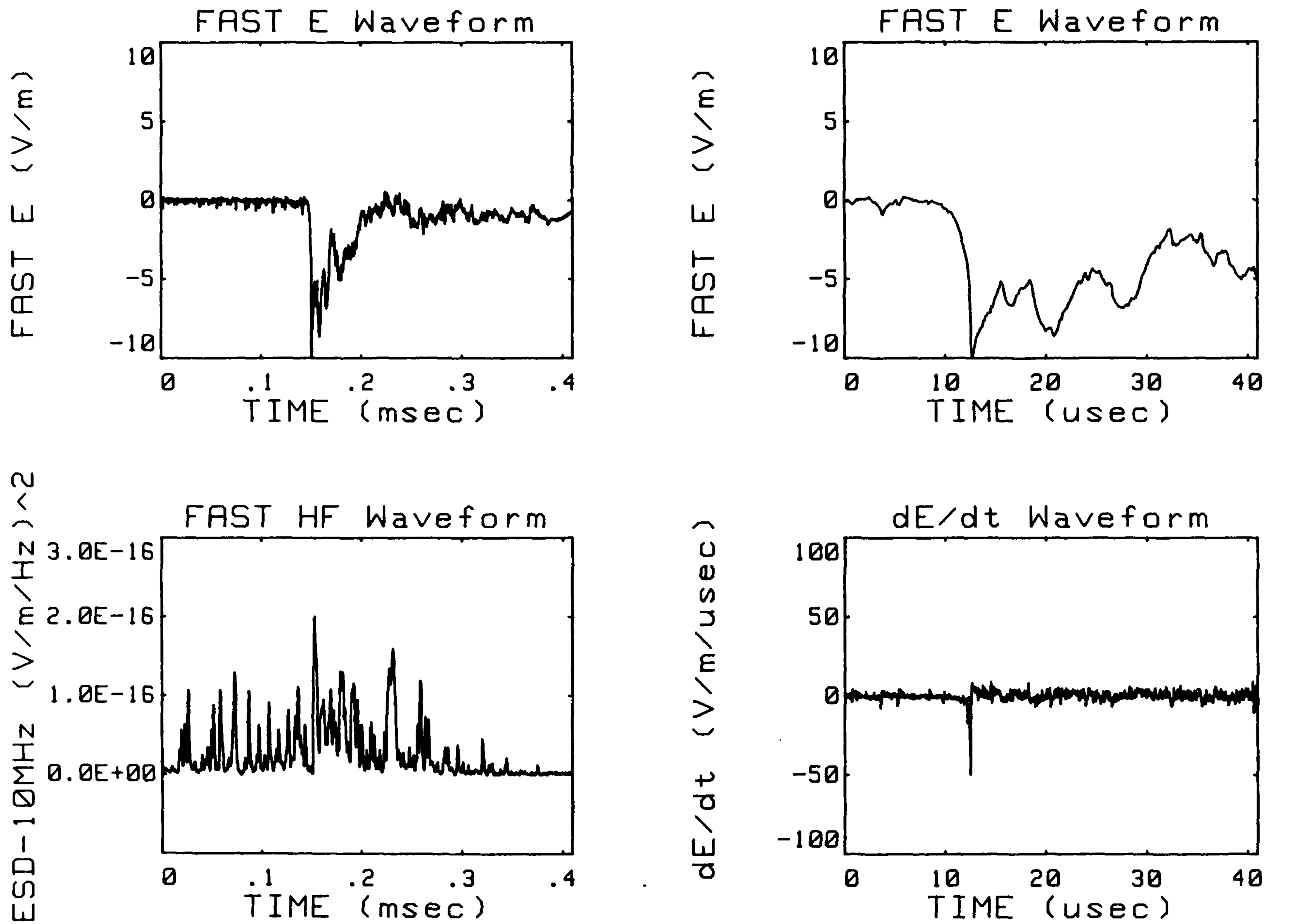

20:32:53.971 24 Jul 1985 (45.4 Km)
SLOW E Waveform
SLOW E (V/m)
10
5
0
-5
-10
0
.2
.4
.6
.8
1
TIME (sec)
SLOW HF Waveform
ESD-10MHz (V/m/Hz)^2
3.0E-16
2.0E-16
1.0E-16
0.0E+00
0
.2
.4
.6
.8
1
TIME (sec)

205203328.225 1985 Stepped Leader (40.9 Km)

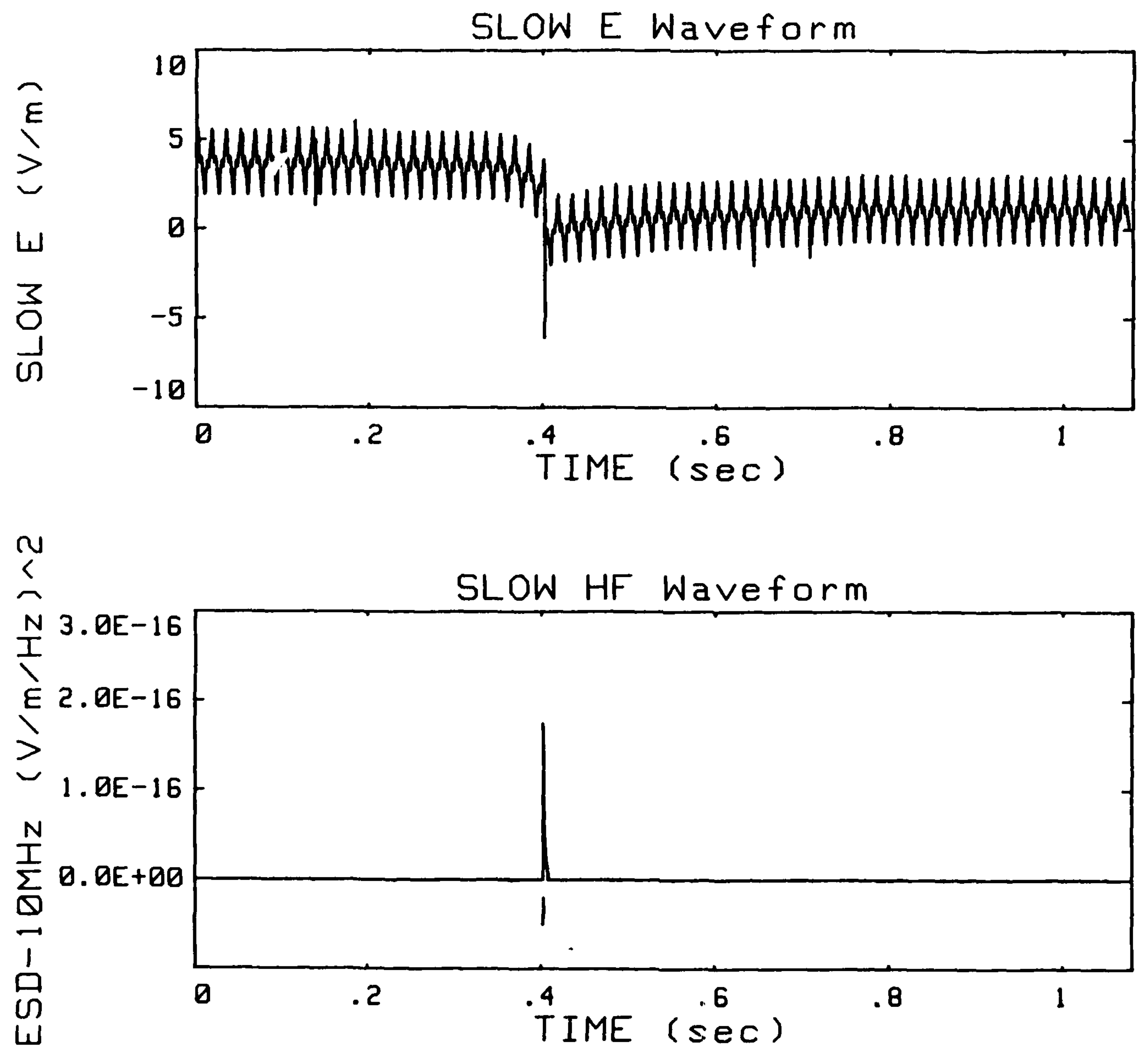


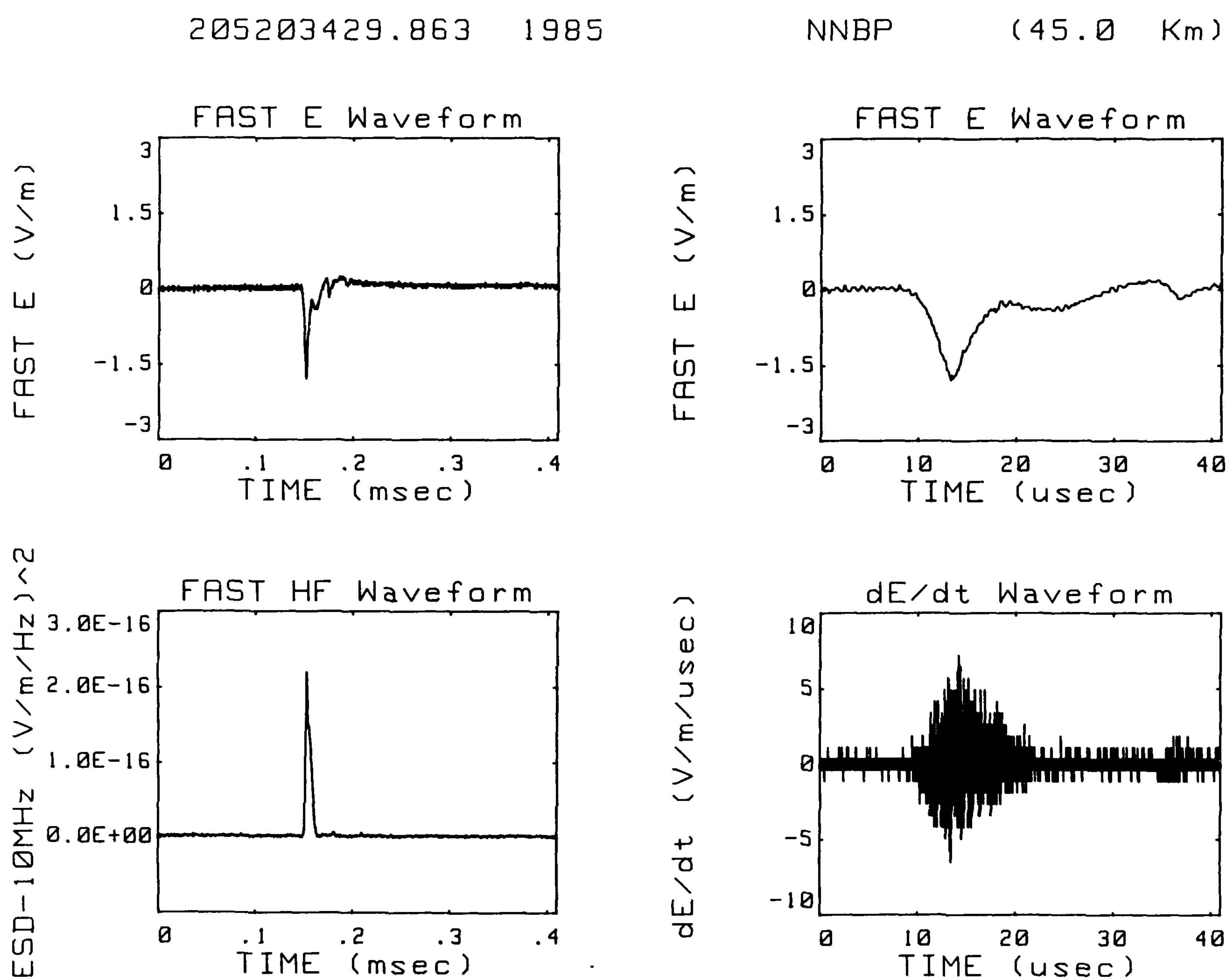

20:33:27.831 24 Jul 1985 (40.9 Km)
SLOW E Waveform
SLOW E (V/m)
10
5
0
-5
-10
0
.2
.4
.6
.8
1
TIME (sec)
SLOW HF Waveform
ESD-10MHz (V/m/Hz)^2
1.0E-15
7.5E-16
5.0E-16
2.5E-16
0.0E+00
0
.2
.4
.6
.8
1
TIME (sec)

205203407.795 1985 1st RS (46.7 Km)



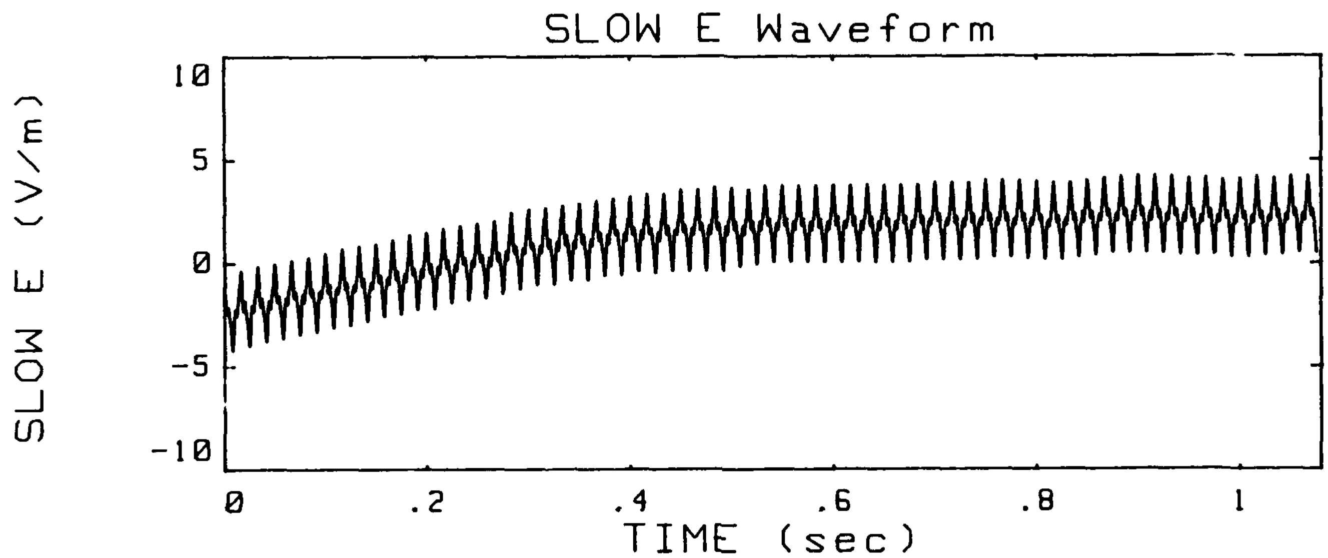
20:34:07.405 24 Jul 1985 (46.7 Km)

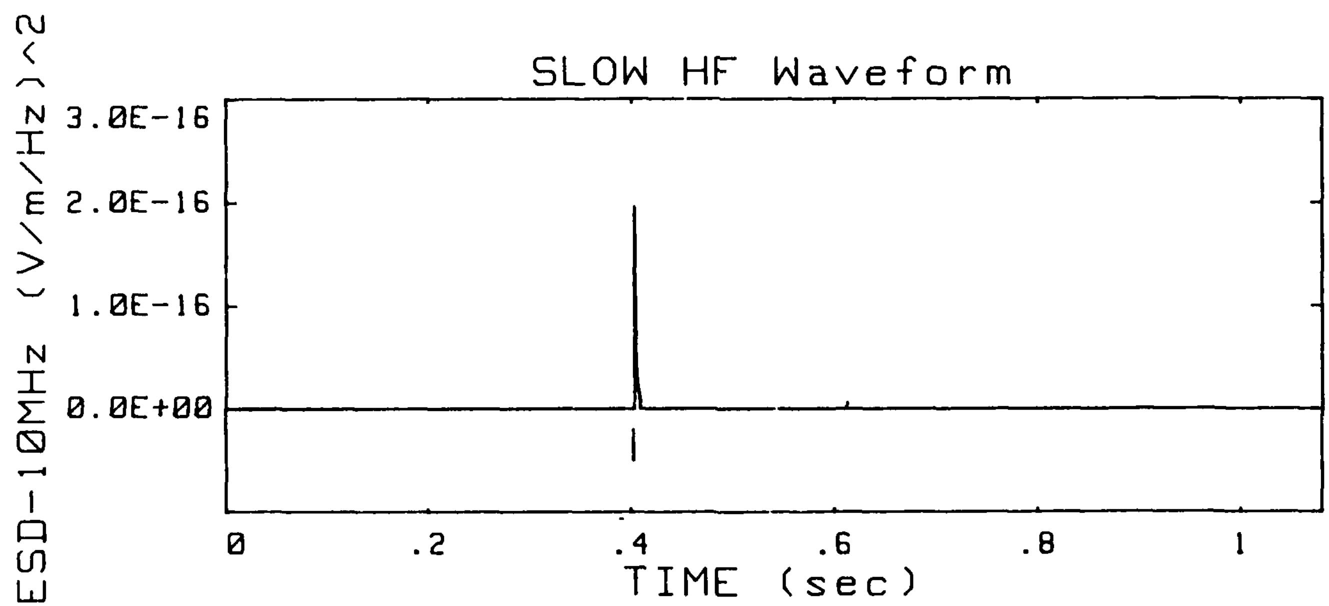


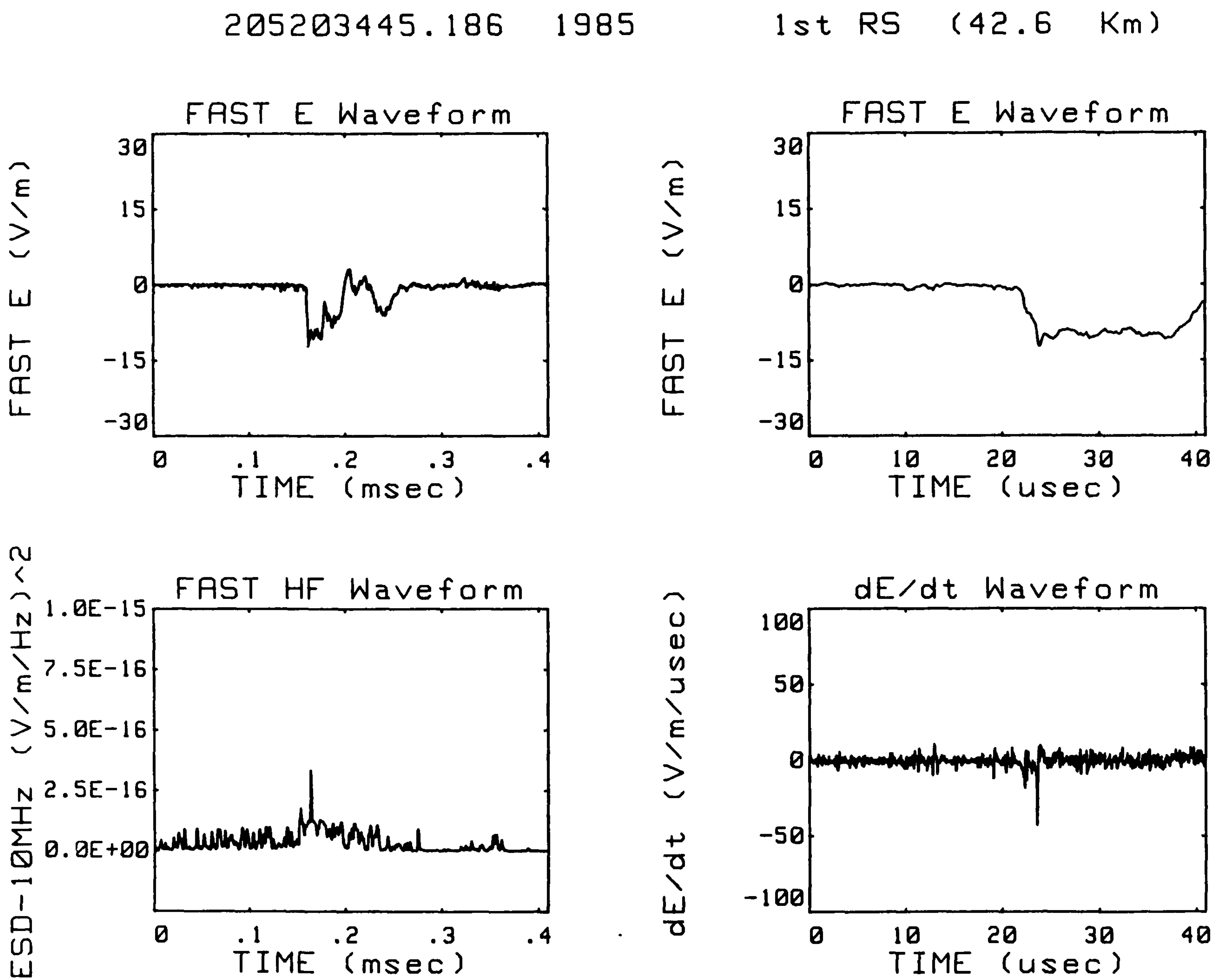


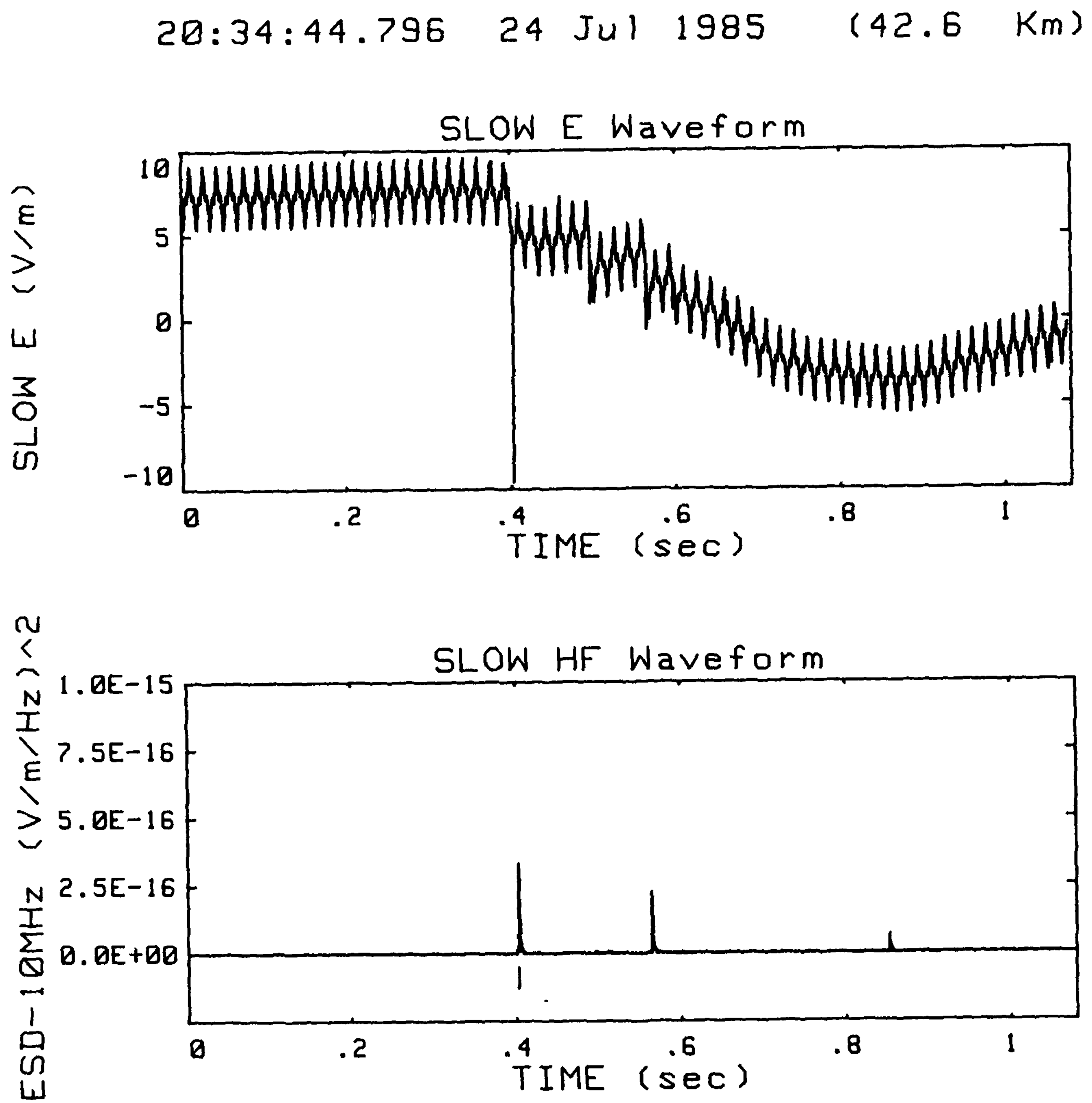
205203429.863 1985
NNBP (45.0 Km)
FAST E Waveform
FAST E (V/m)
3
1.5
0
-1.5
-3
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
3
1.5
0
-1.5
-3
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-10MHz (V/m/Hz)^2
3.0E-16
2.0E-16
1.0E-16
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
10
5
0
-5
-10
0
10
20
30
40
TIME (usec)

20:34:29.473 24 Jul 1985 (45.0 Km)

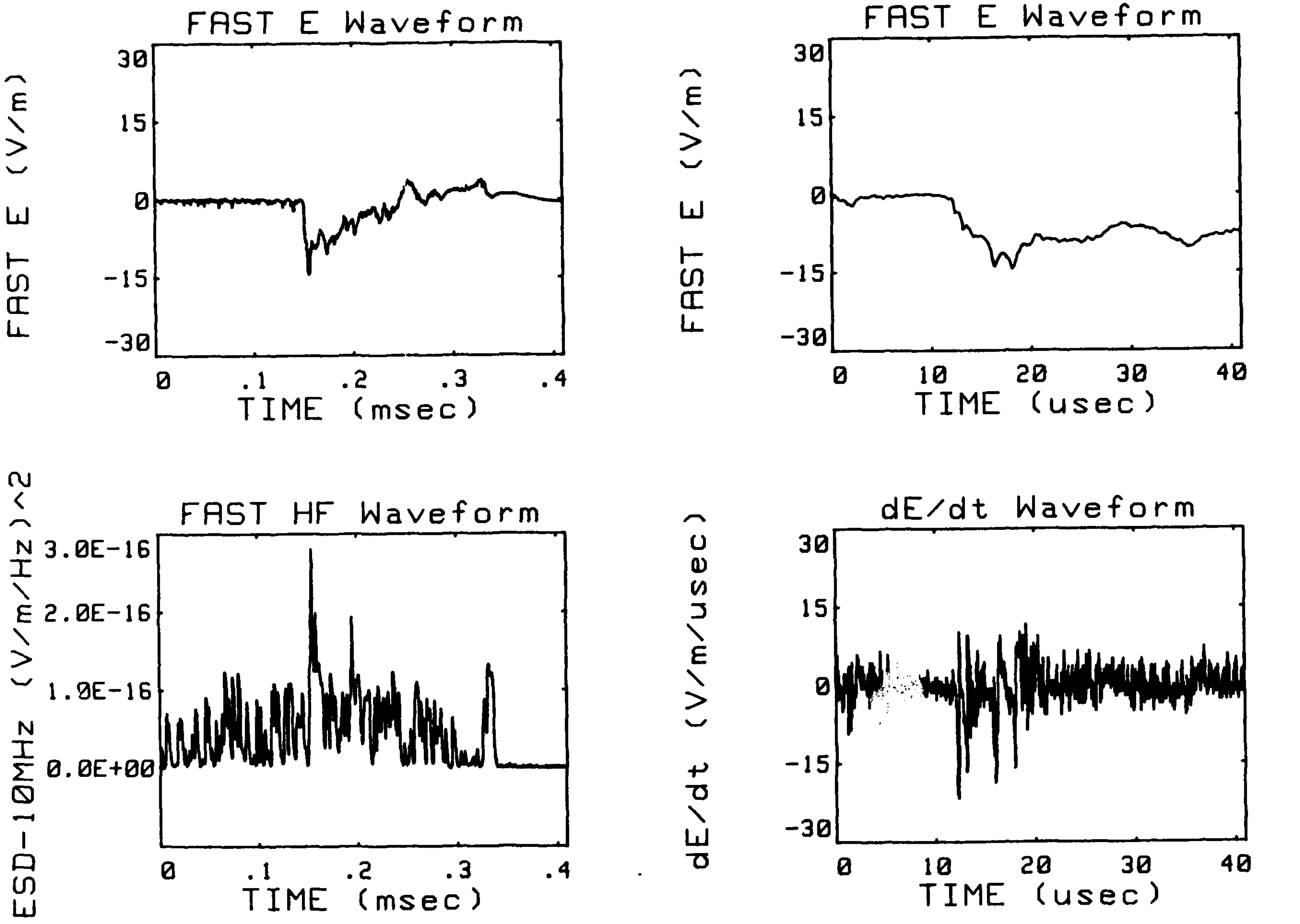




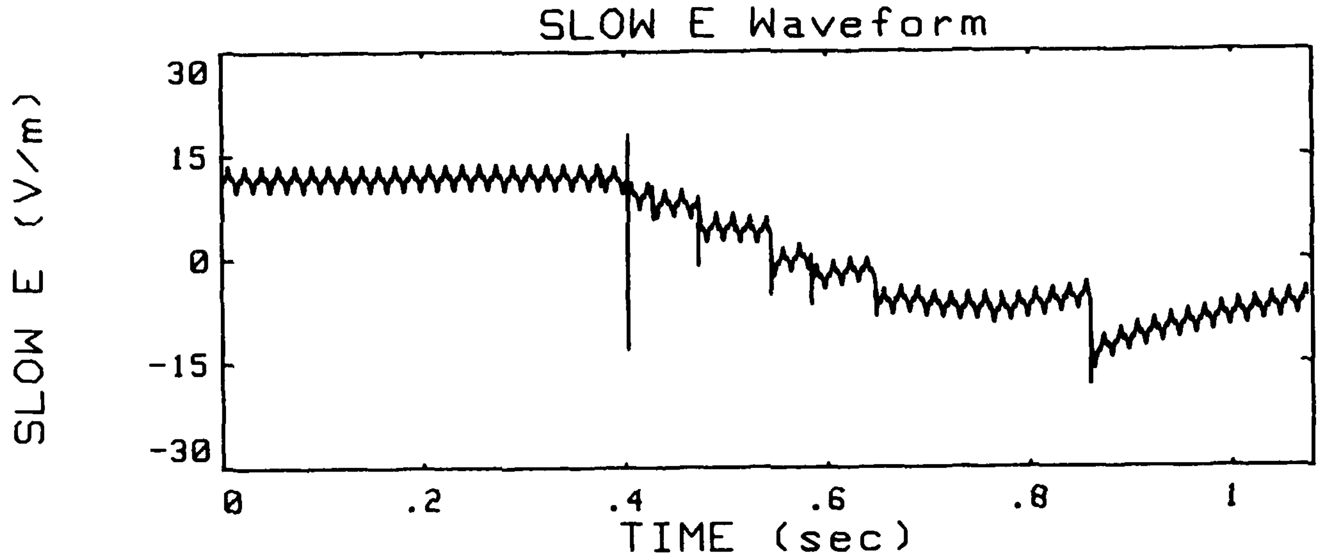

205203445.186 1985
1st RS (42.6 Km)
FAST E Waveform
FAST E (V/m)
30
15
0
-15
-30
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
30
15
0
-15
-30
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-10MHz (V/m/Hz)^2
1.0E-15
7.5E-16
5.0E-16
2.5E-16
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
100
50
0
-50
-100
0
10
20
30
40
TIME (usec)

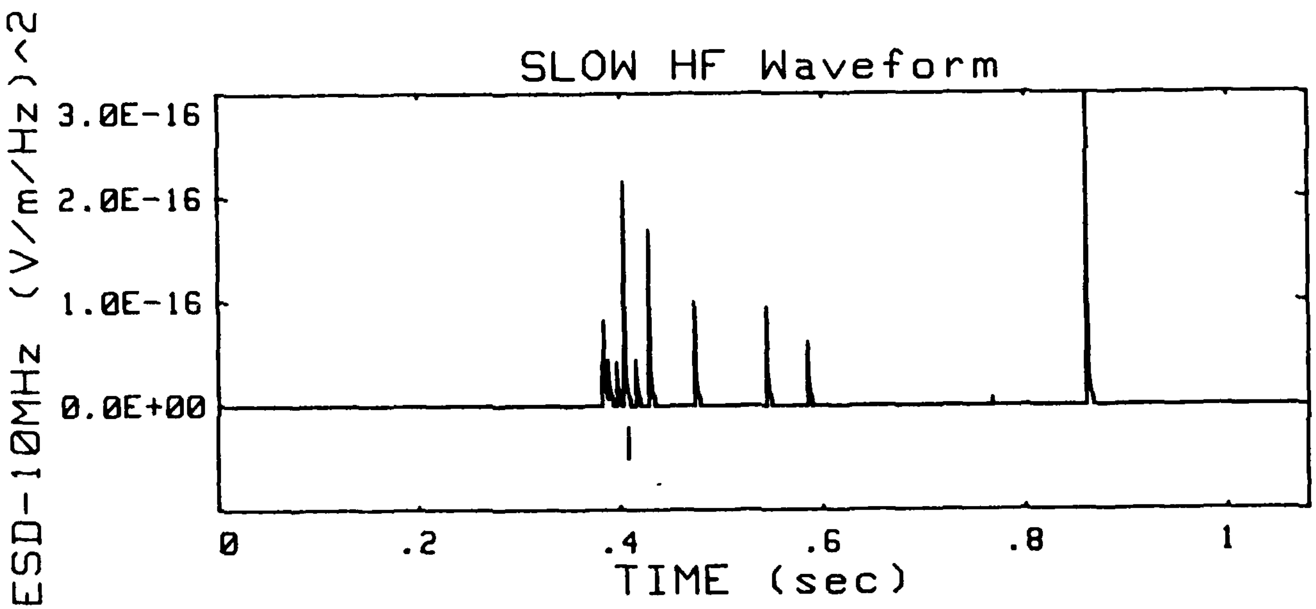

20:34:44.796 24 Jul 1985 (42.6 Km)
SLOW E Waveform
SLOW E (V/m)
10
5
0
-5
-10
0
.2
.4
.6
.8
1
TIME (sec)
SLOW HF Waveform
ESD-10MHz (V/m/Hz)^2
1.0E-15
7.5E-16
5.0E-16
2.5E-16
0.0E+00
0
.2
.4
.6
.8
1
TIME (sec)

205203525.273 1985 Multiple Gnd RS (42.6 Km)

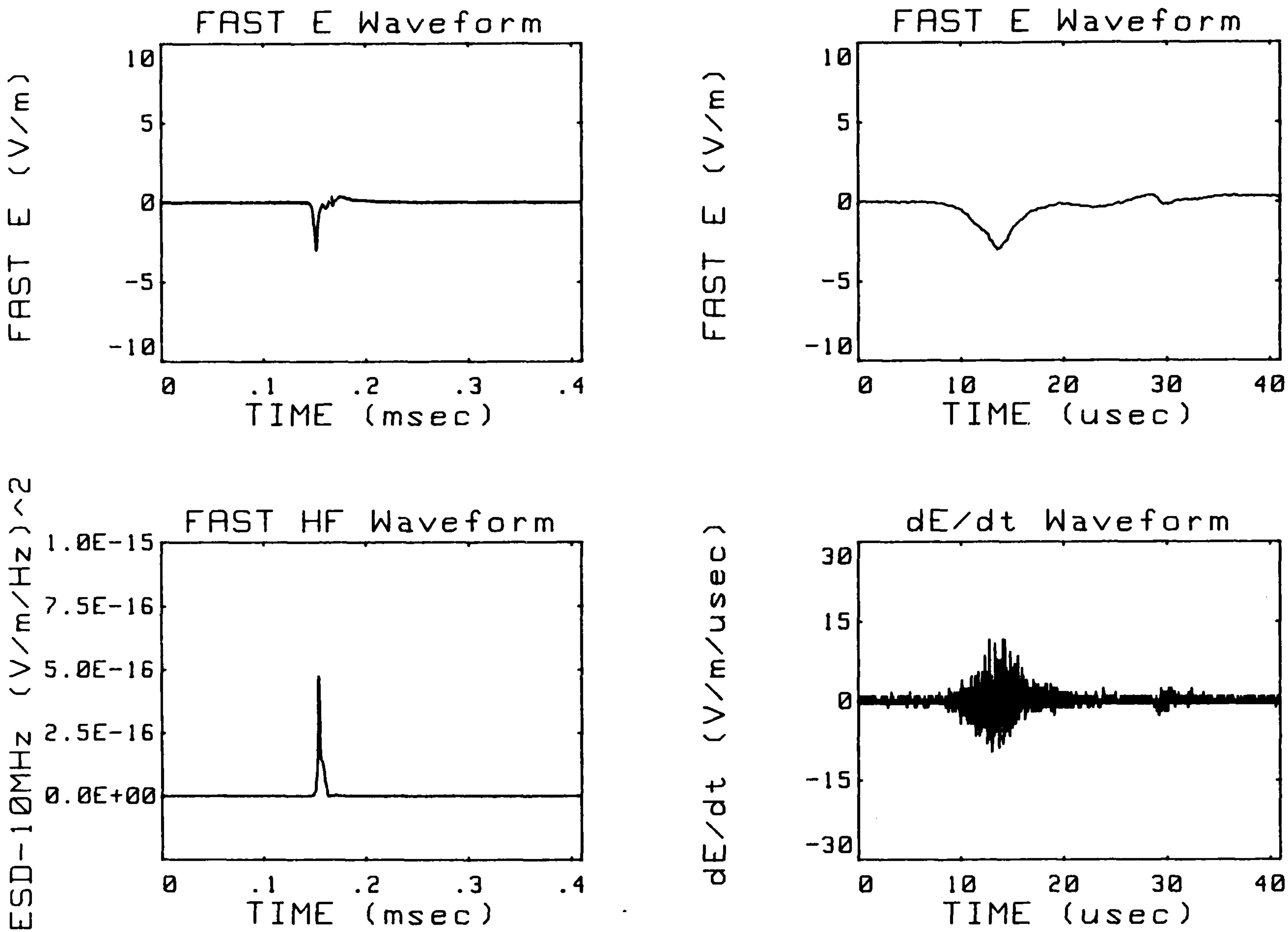


20:35:24.878 24 Jul 1985 (42.6 Km)

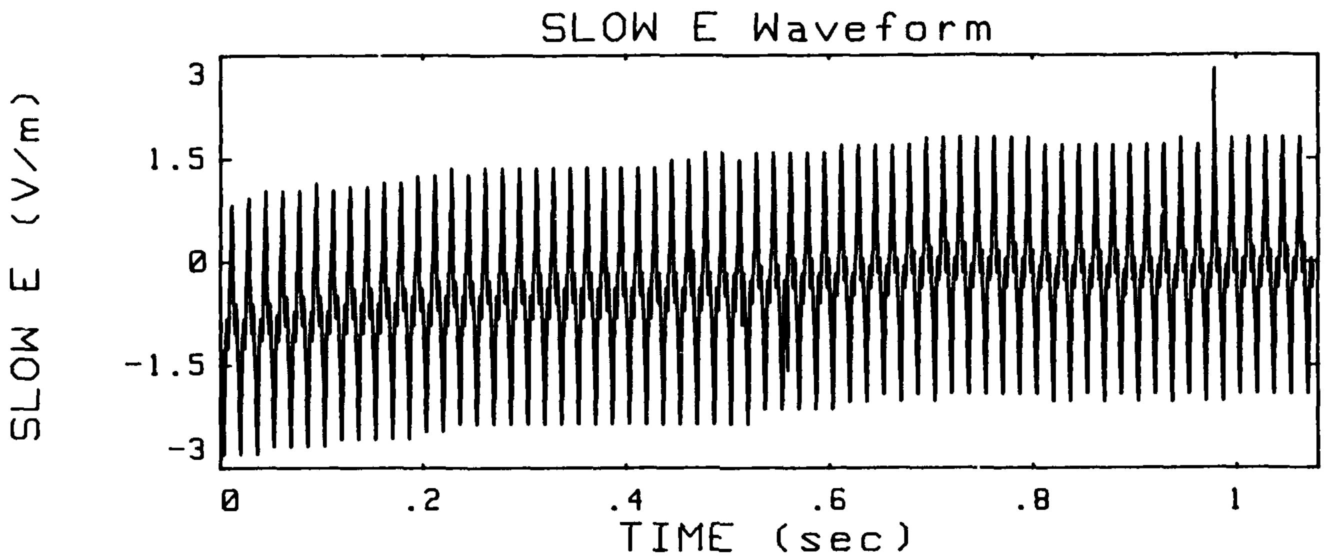


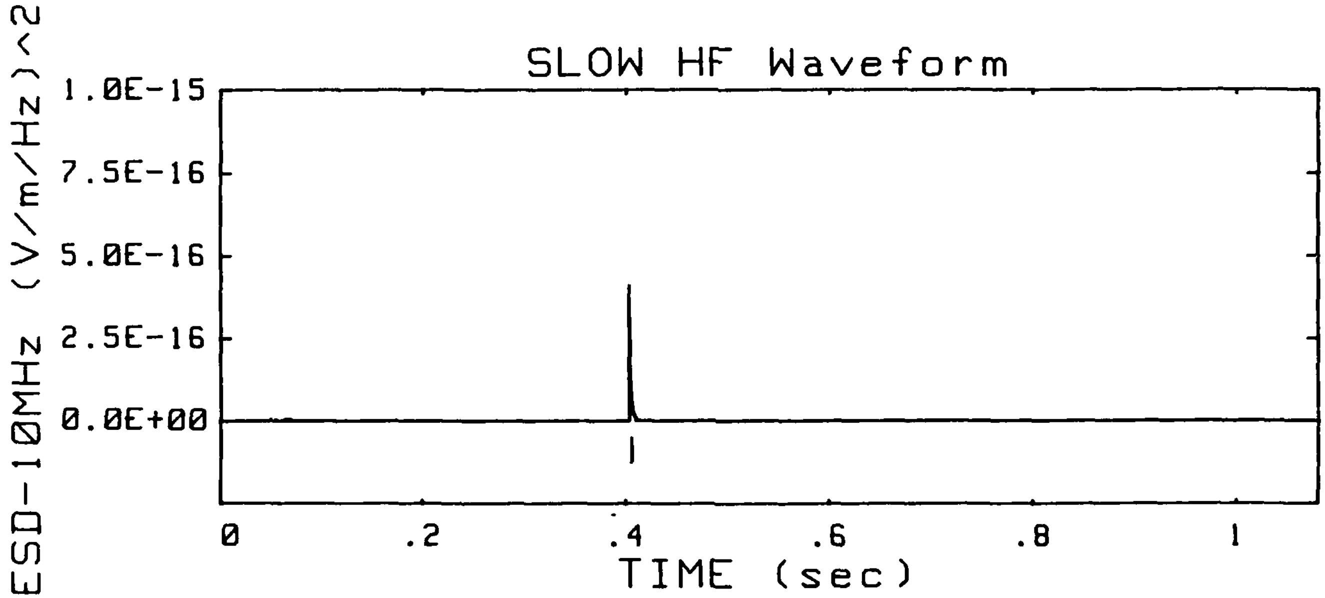


205203534.667 1985 NNBP (45.0 Km)

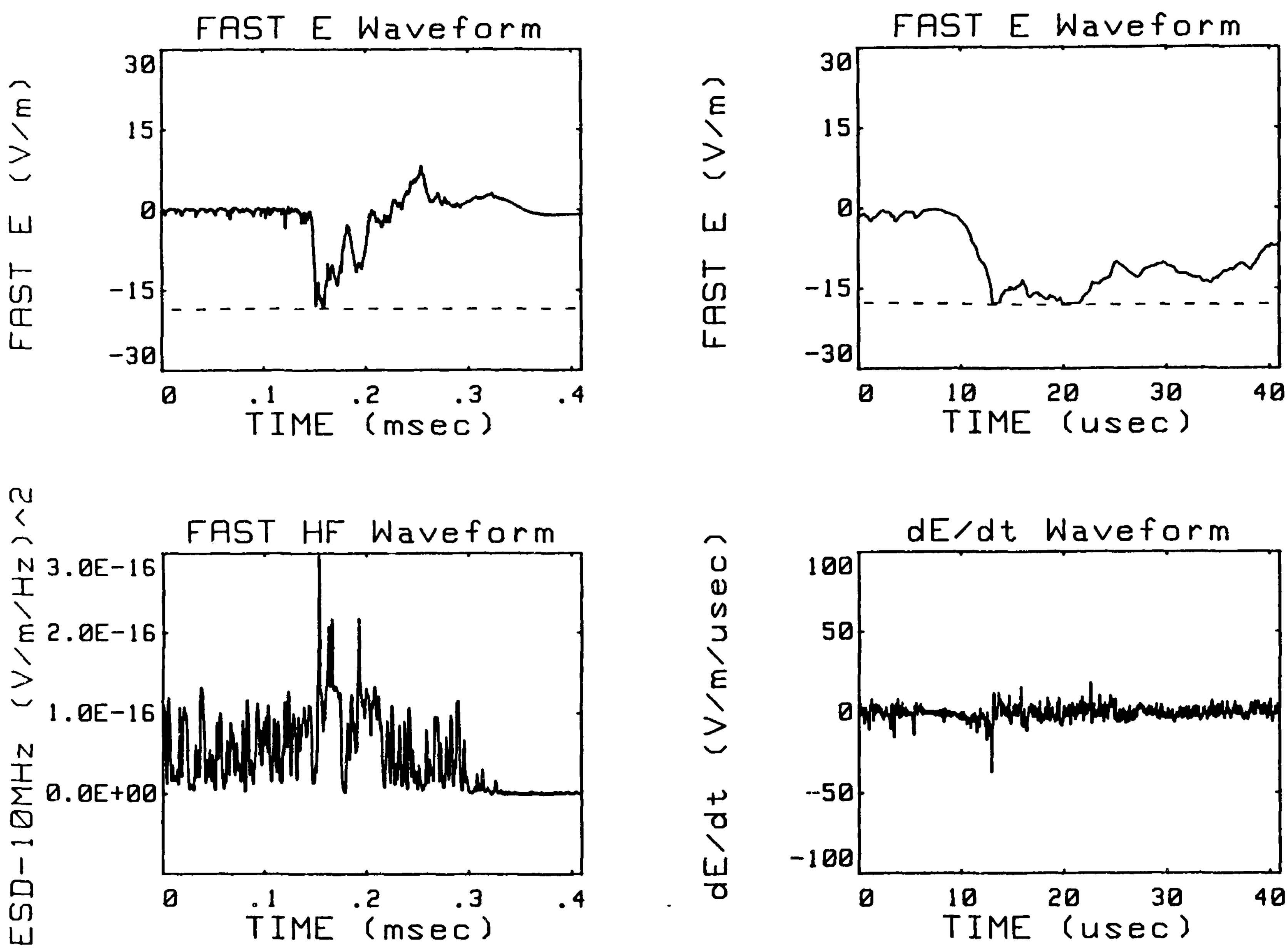


20:35:34.274 24 Jul 1985 (45.0 Km)

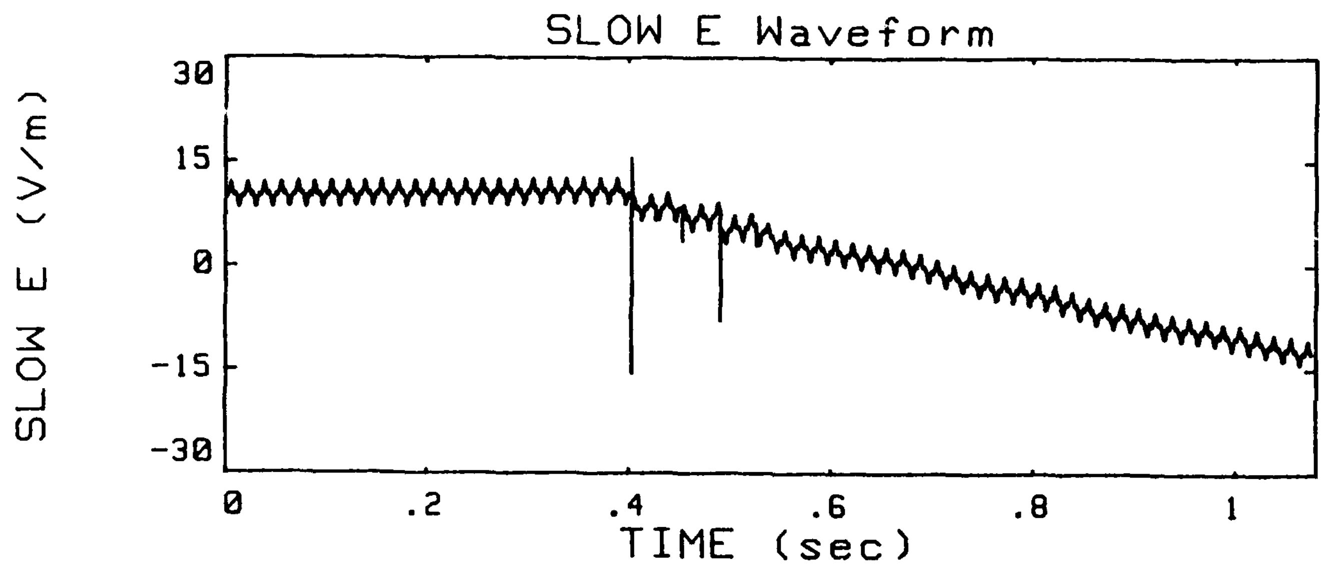


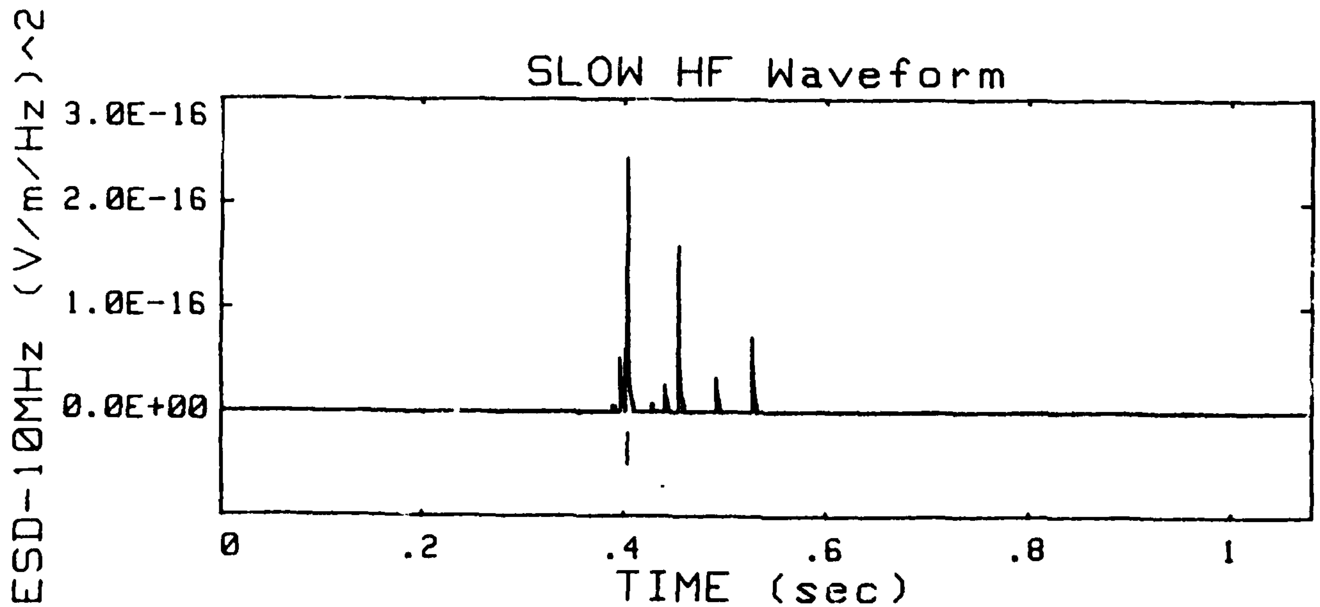


205203809.461   1985   1st RS   (43.4   Km)

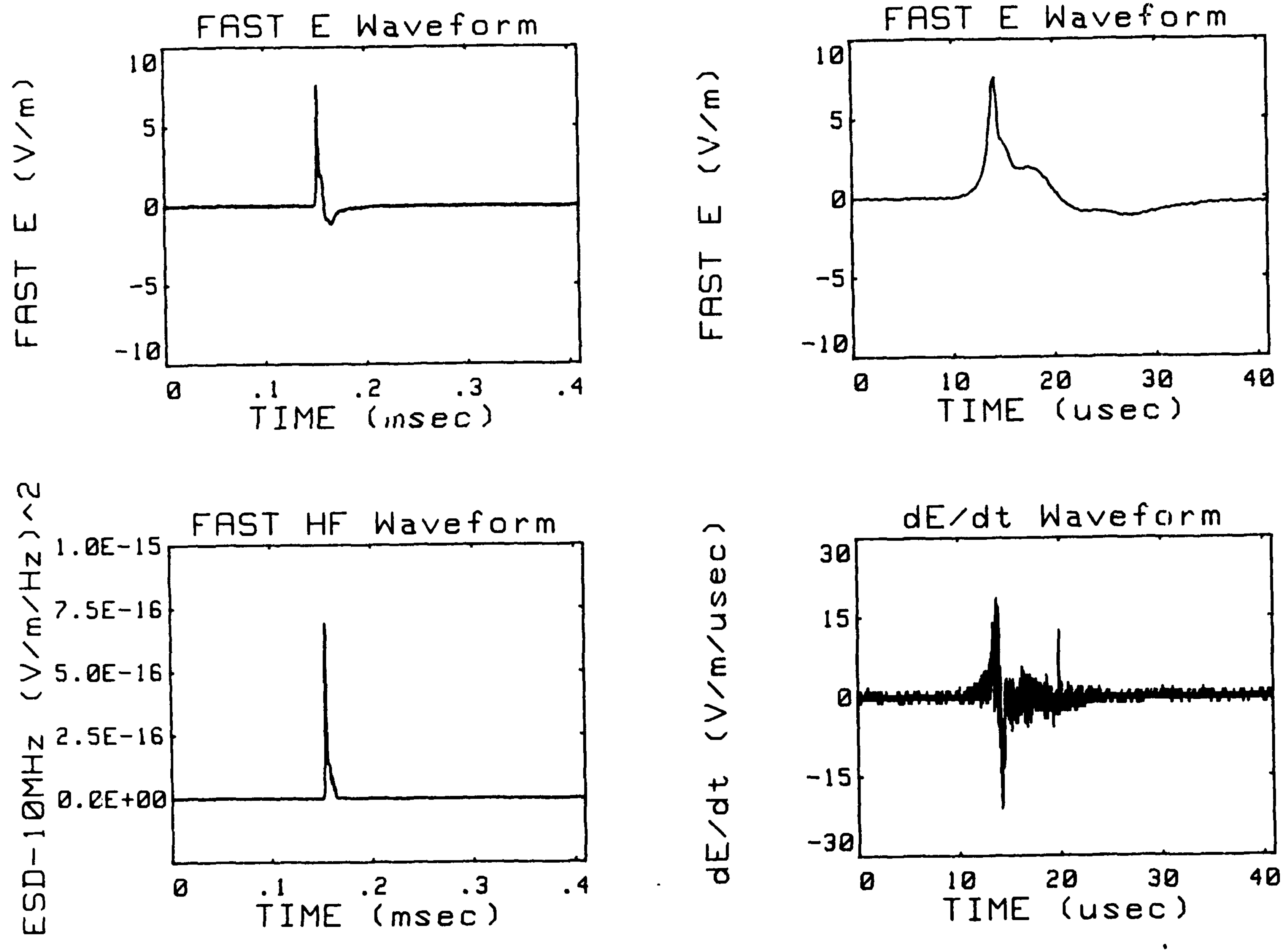


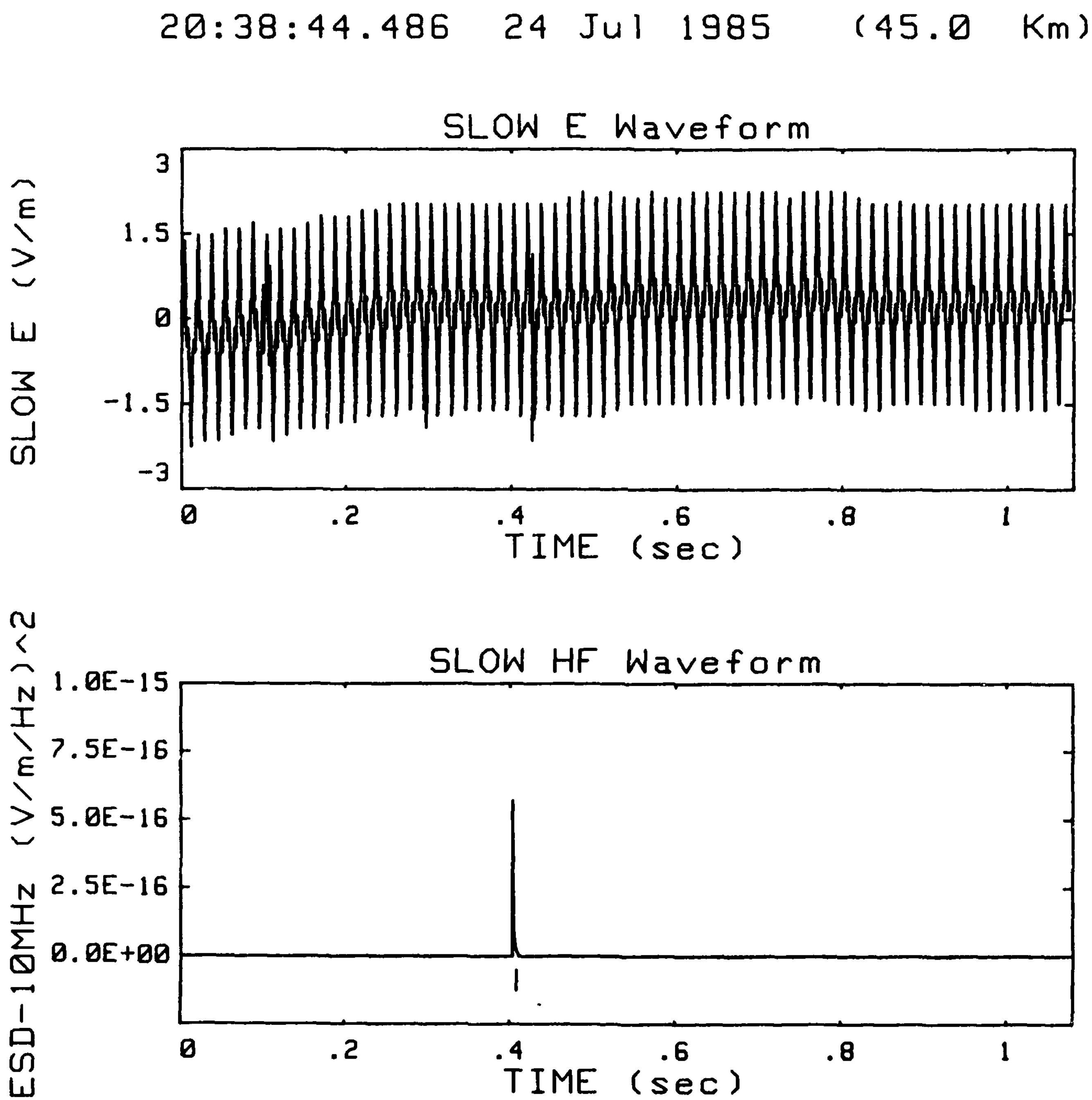
20:38:09.070 24 Jul 1985 (43.4 Km)



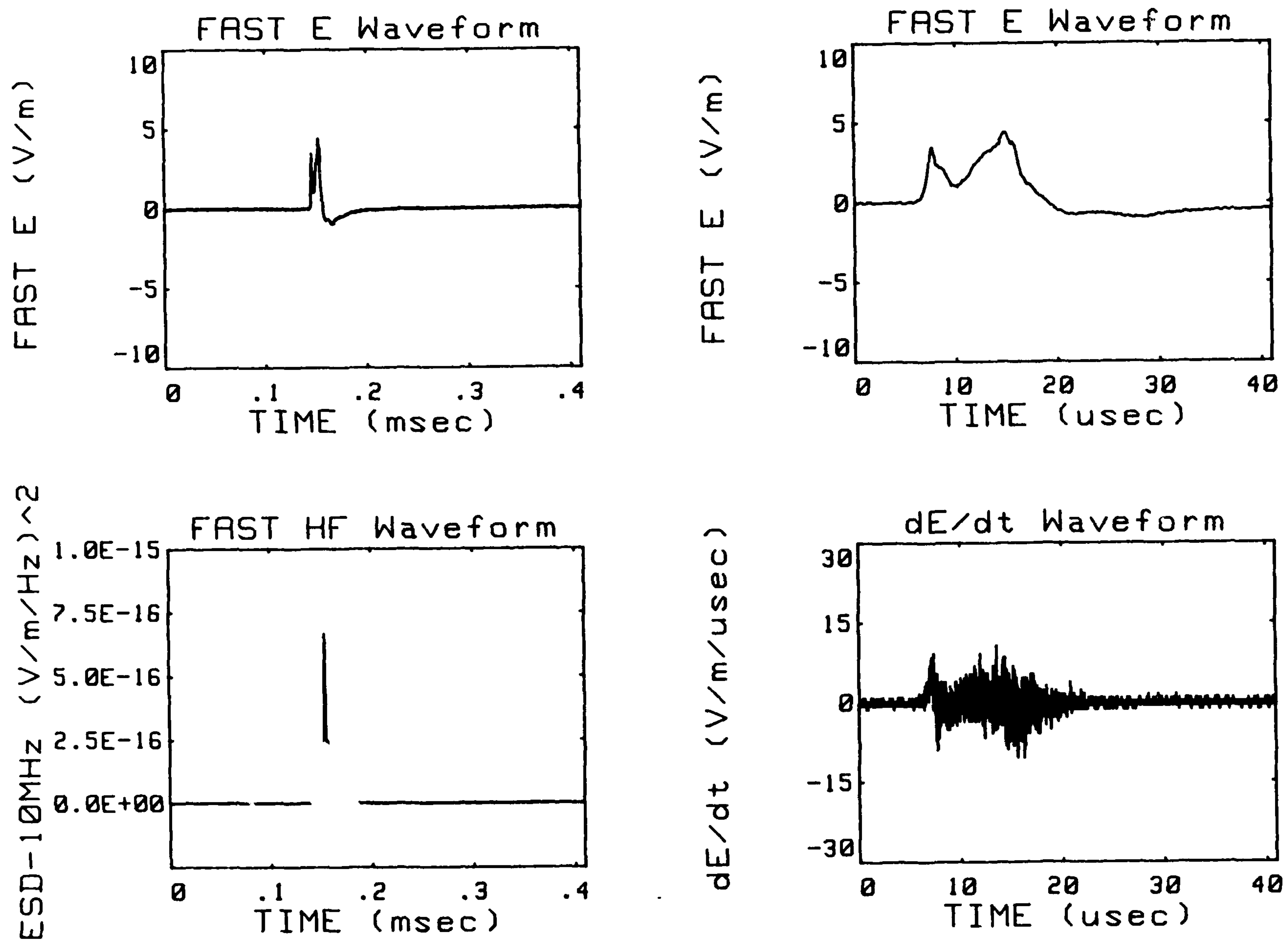


205203844.881 1985 NPBP (45.0 Km)

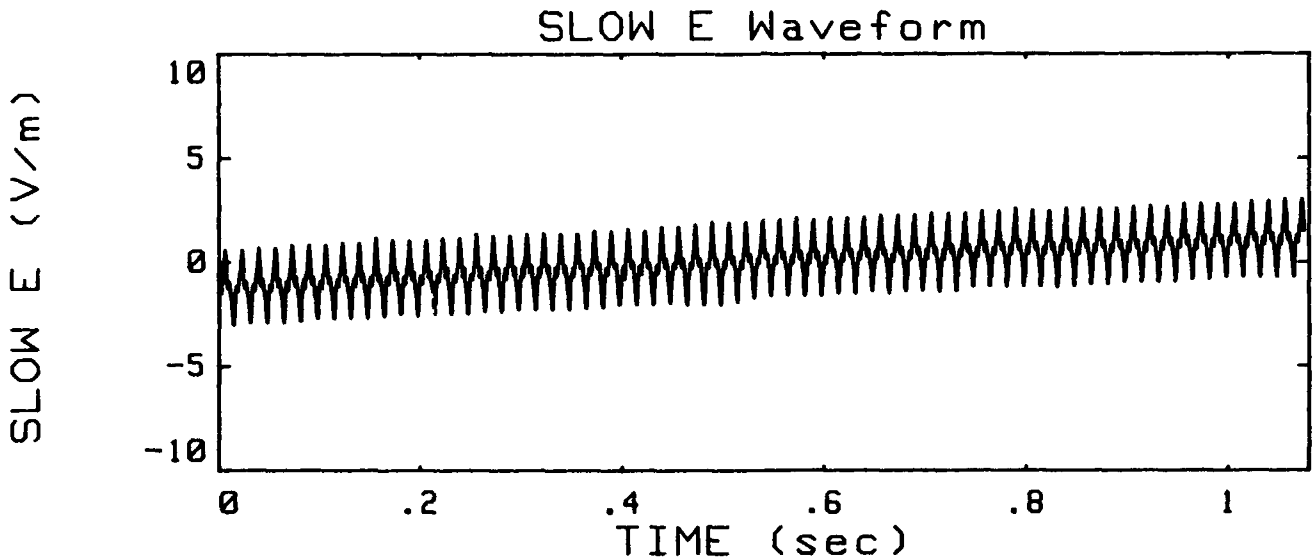


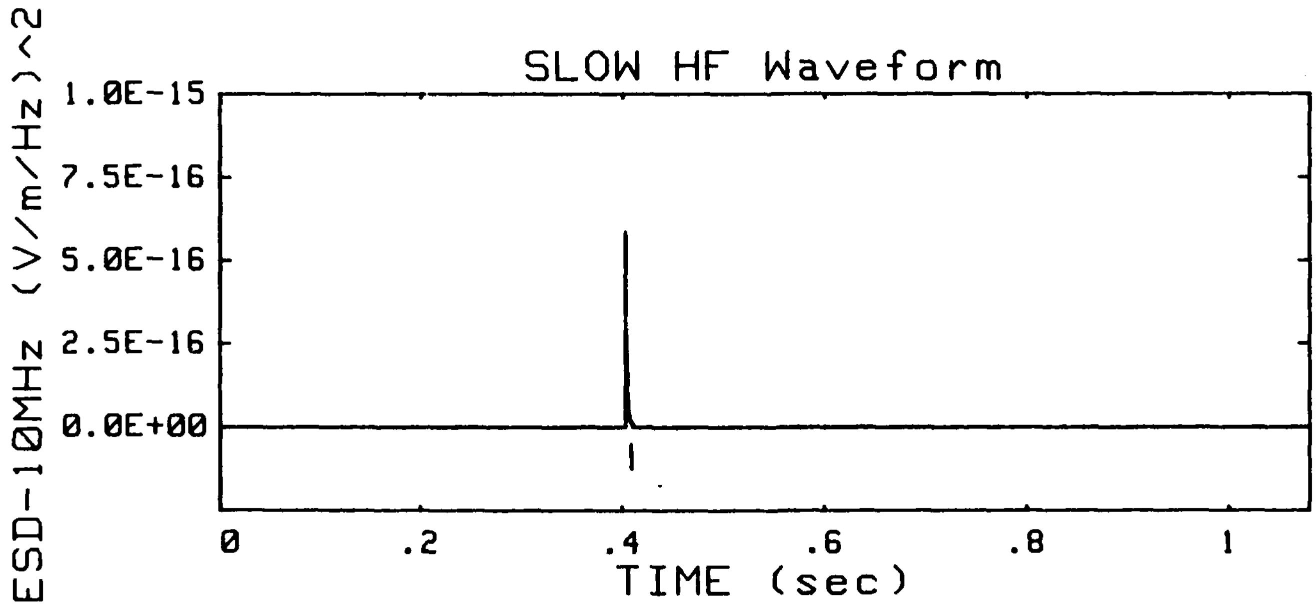

20:38:44.486 24 Jul 1985 (45.0 Km)
SLOW E Waveform
SLOW E (V/m)
3
1.5
0
-1.5
-3
0
.2
.4
.6
.8
1
TIME (sec)
SLOW HF Waveform
ESD-10MHz (V/m/Hz)^2
1.0E-15
7.5E-16
5.0E-16
2.5E-16
0.0E+00
0
.2
.4
.6
.8
1
TIME (sec)

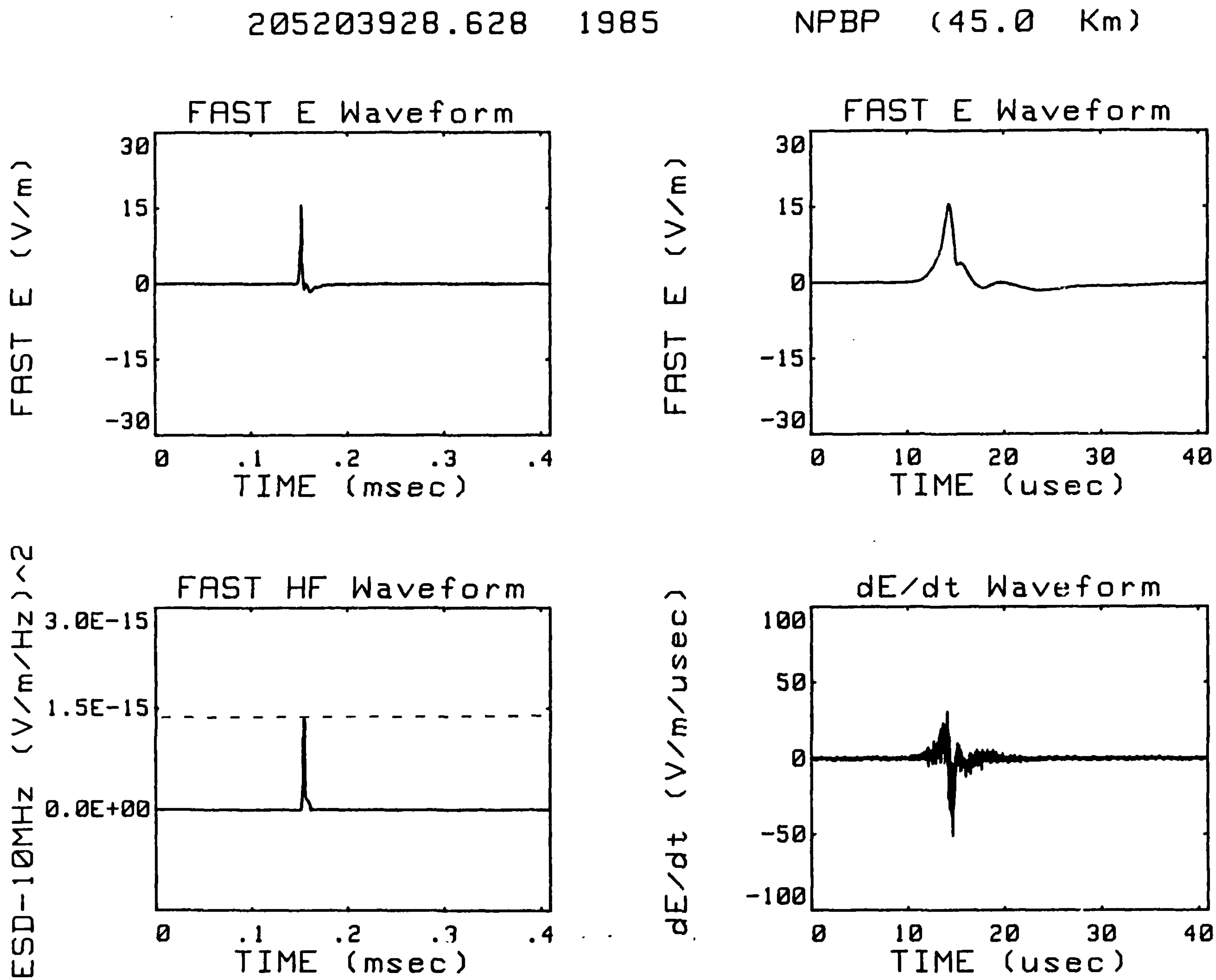
205203850.894 1985 NPBP (45.0 Km)



20:38:50.498 24 Jul 1985 (45.0 Km)

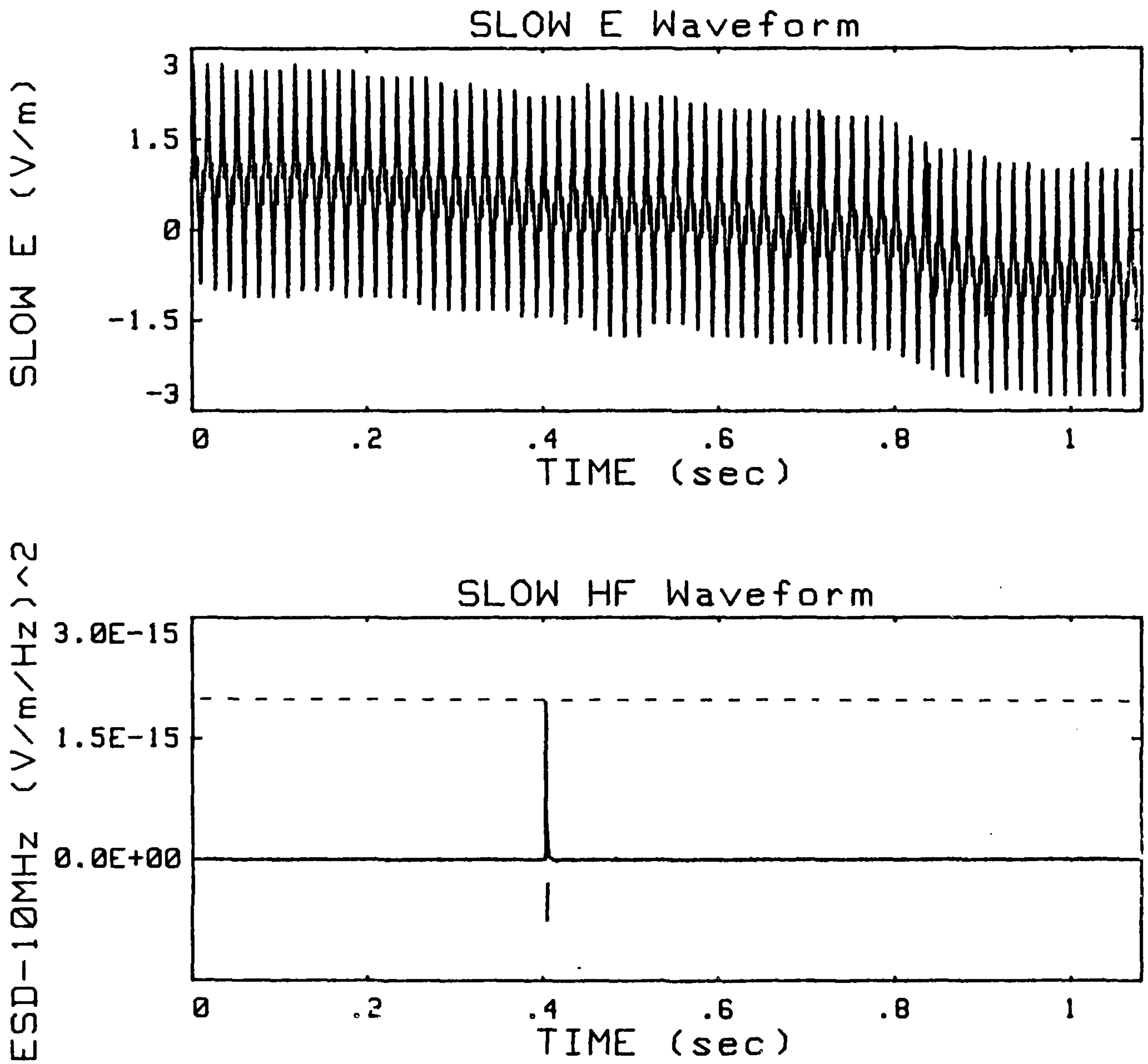




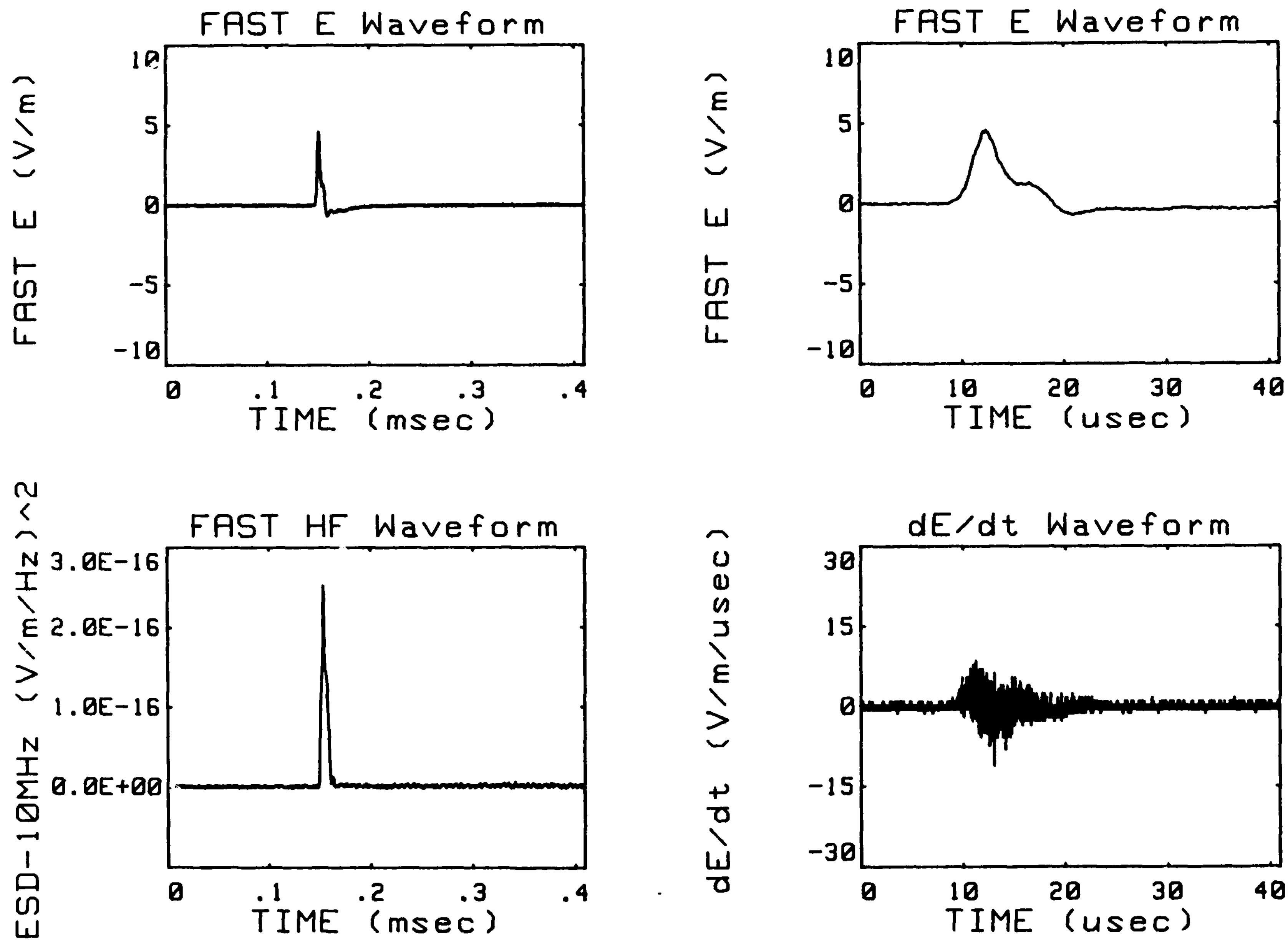


20520392 8.628 1985 NPBP (45.0 Km)
FAST E Waveform
FAST E (V/m)
30
15
0
-15
-30
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
30
15
0
-15
-30
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-10MHz (V/m/Hz)^2
3.0E-15
1.5E-15
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
100
50
0
-50
-100
0
10
20
30
40
TIME (usec)

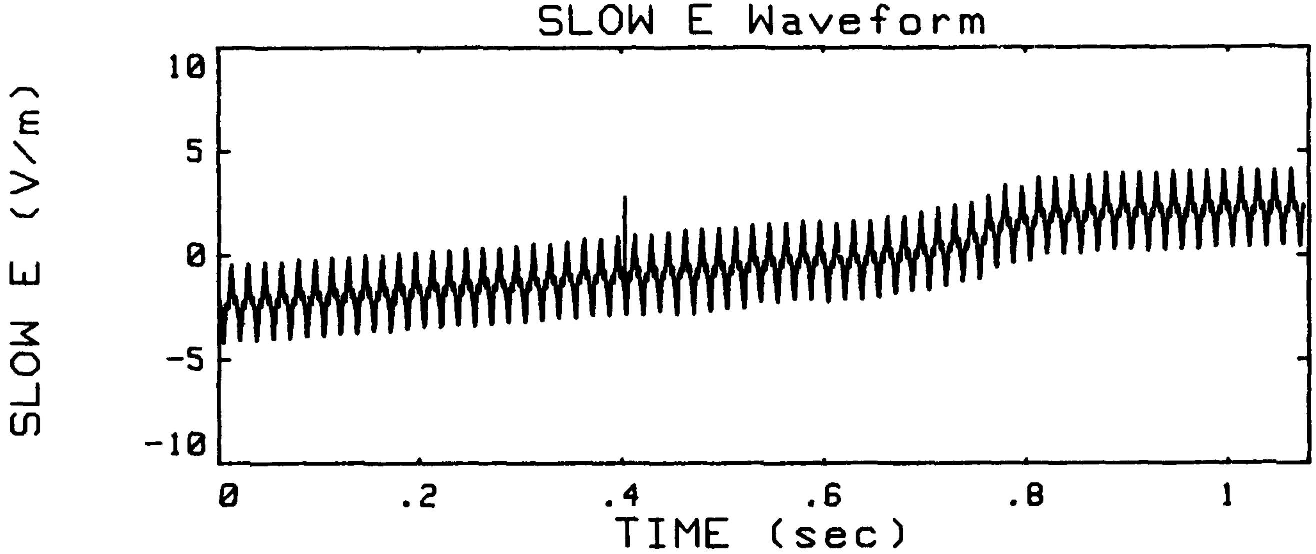
20:39:28.236 24 Jul 1985 (45.0 Km)

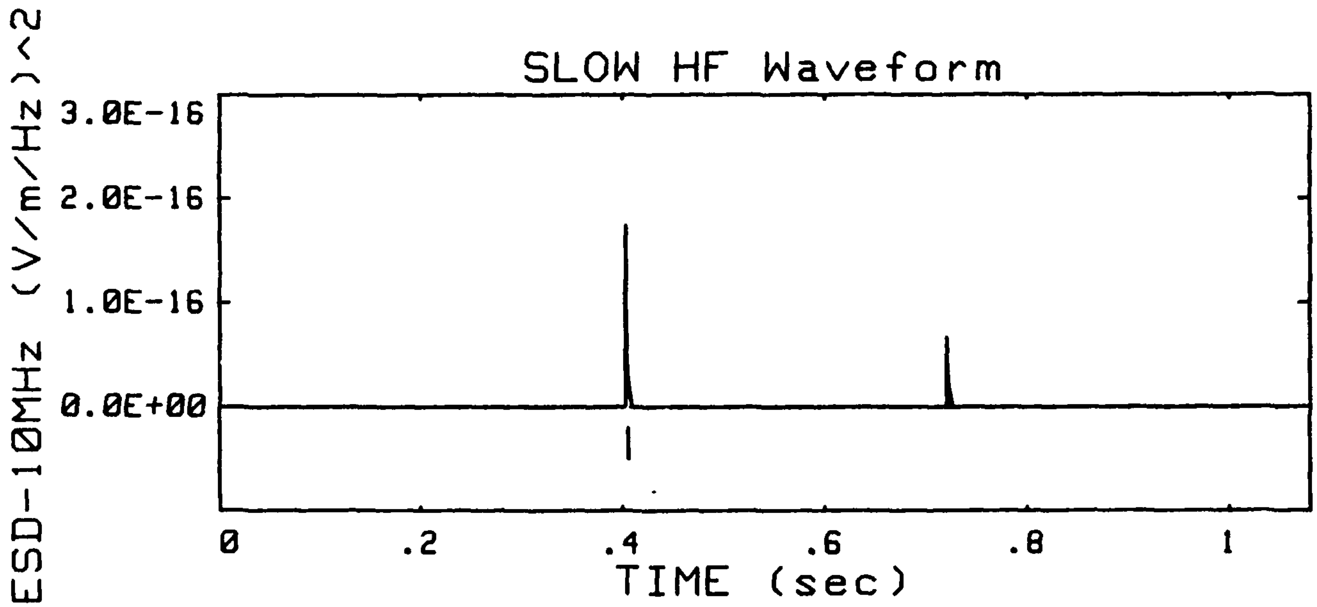


205203947.200 1985 NPBP (45.0 Km)

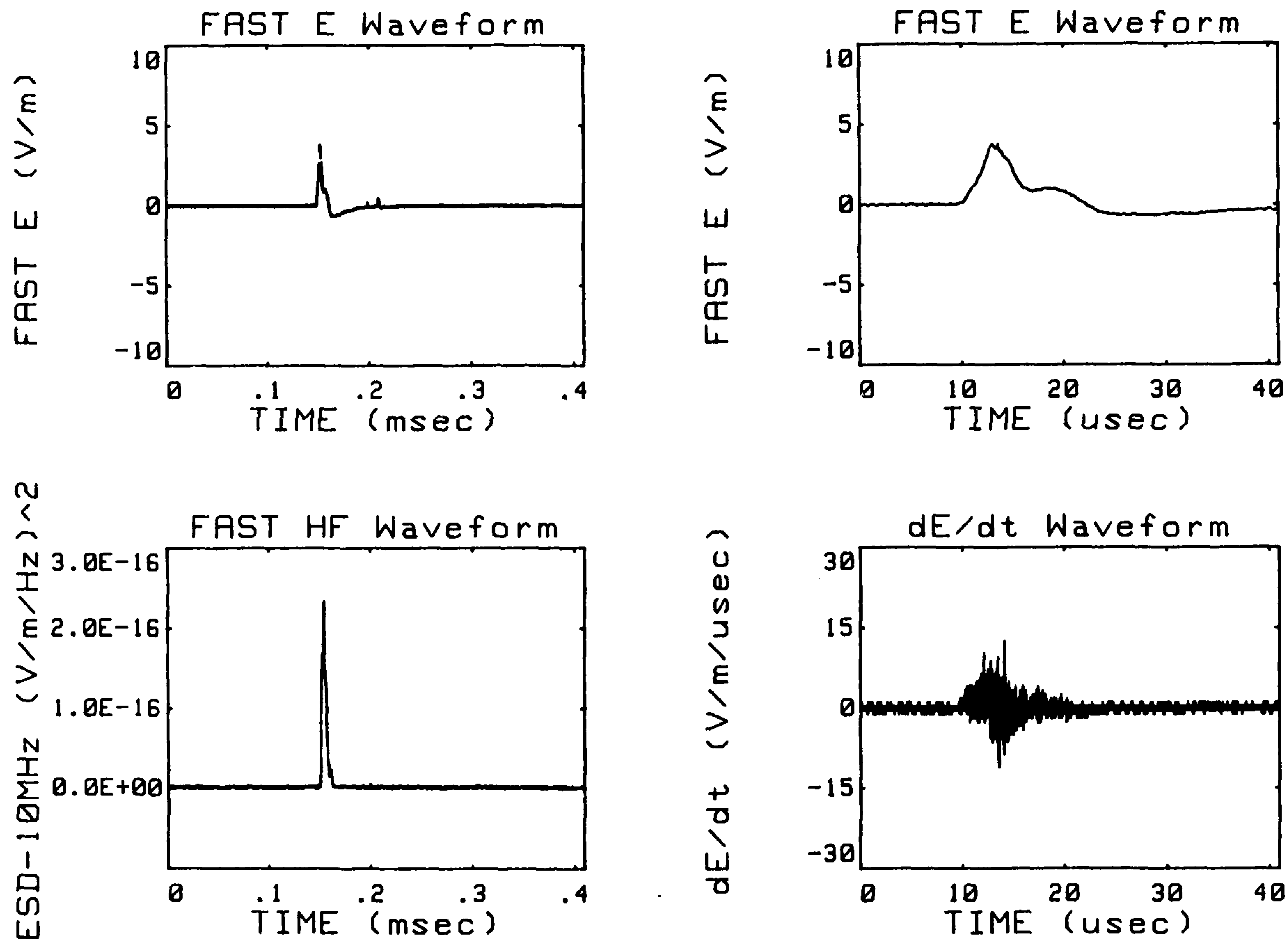


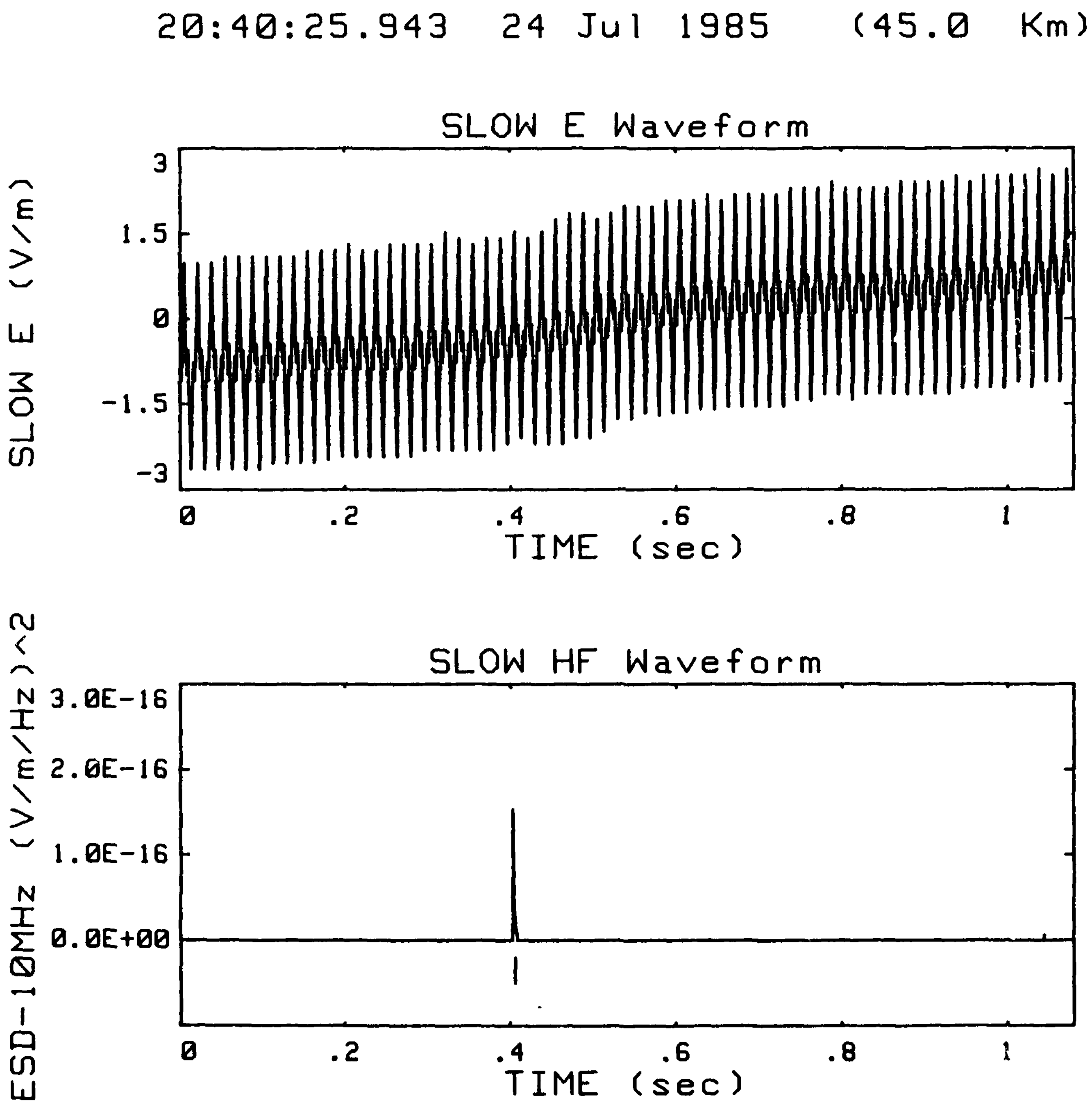
20:39:46.807 24 Jul 1985 (45.0 Km)

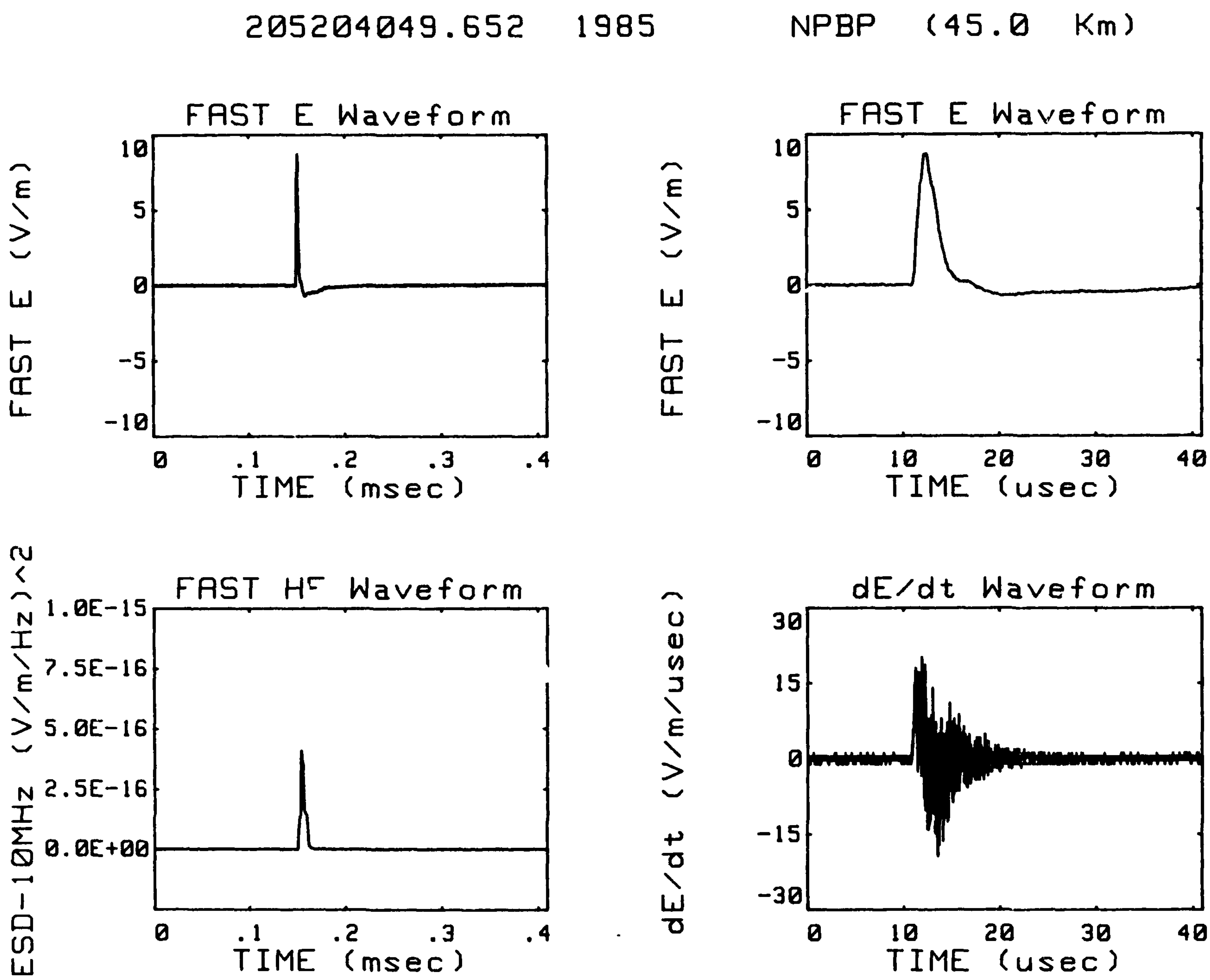




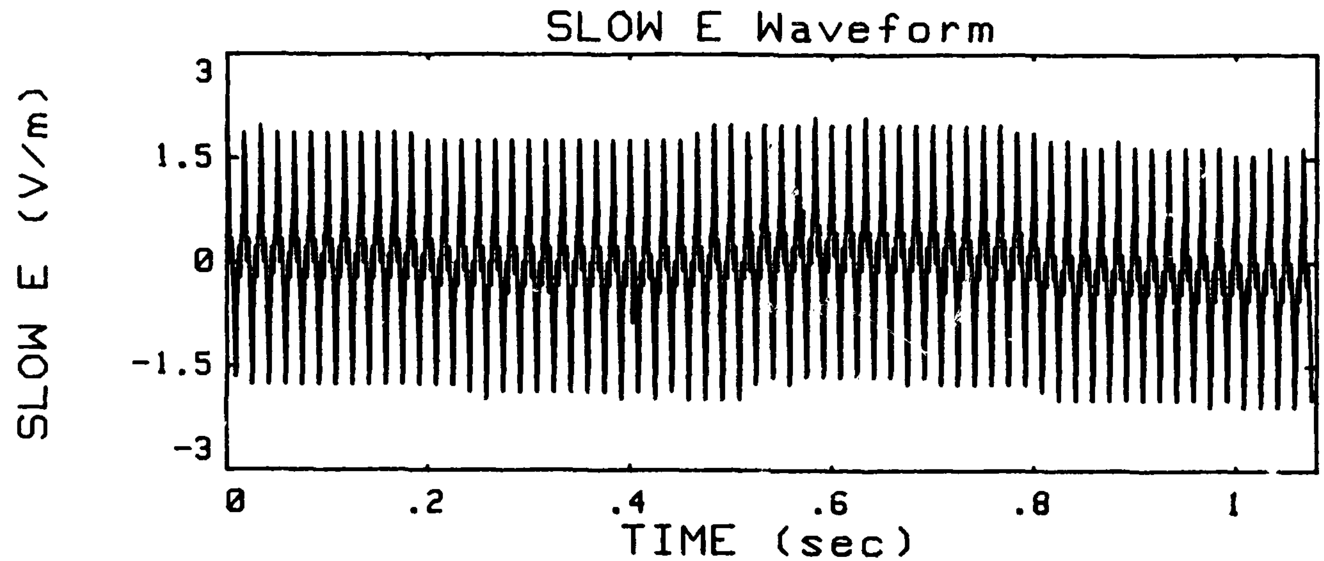
205204026.336 1985 NPBP (45.0 Km)

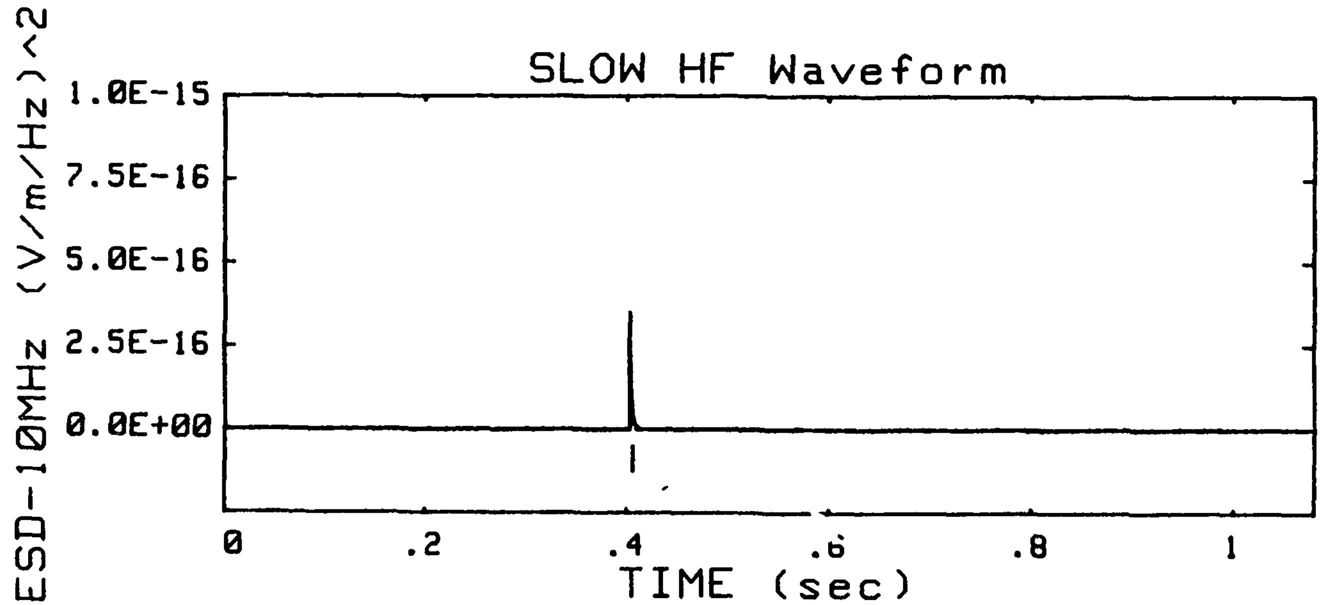



20:40:25.943 24 Jul 1985 (45.0 Km)
SLOW E Waveform
SLOW E (V/m)
3
1.5
0
-1.5
-3
0
.2
.4
.6
.8
1
TIME (sec)
SLOW HF Waveform
ESD-10MHz (V/m/Hz)^2
3.0E-16
2.0E-16
1.0E-16
0.0E+00
0
.2
.4
.6
.8
1
TIME (sec)

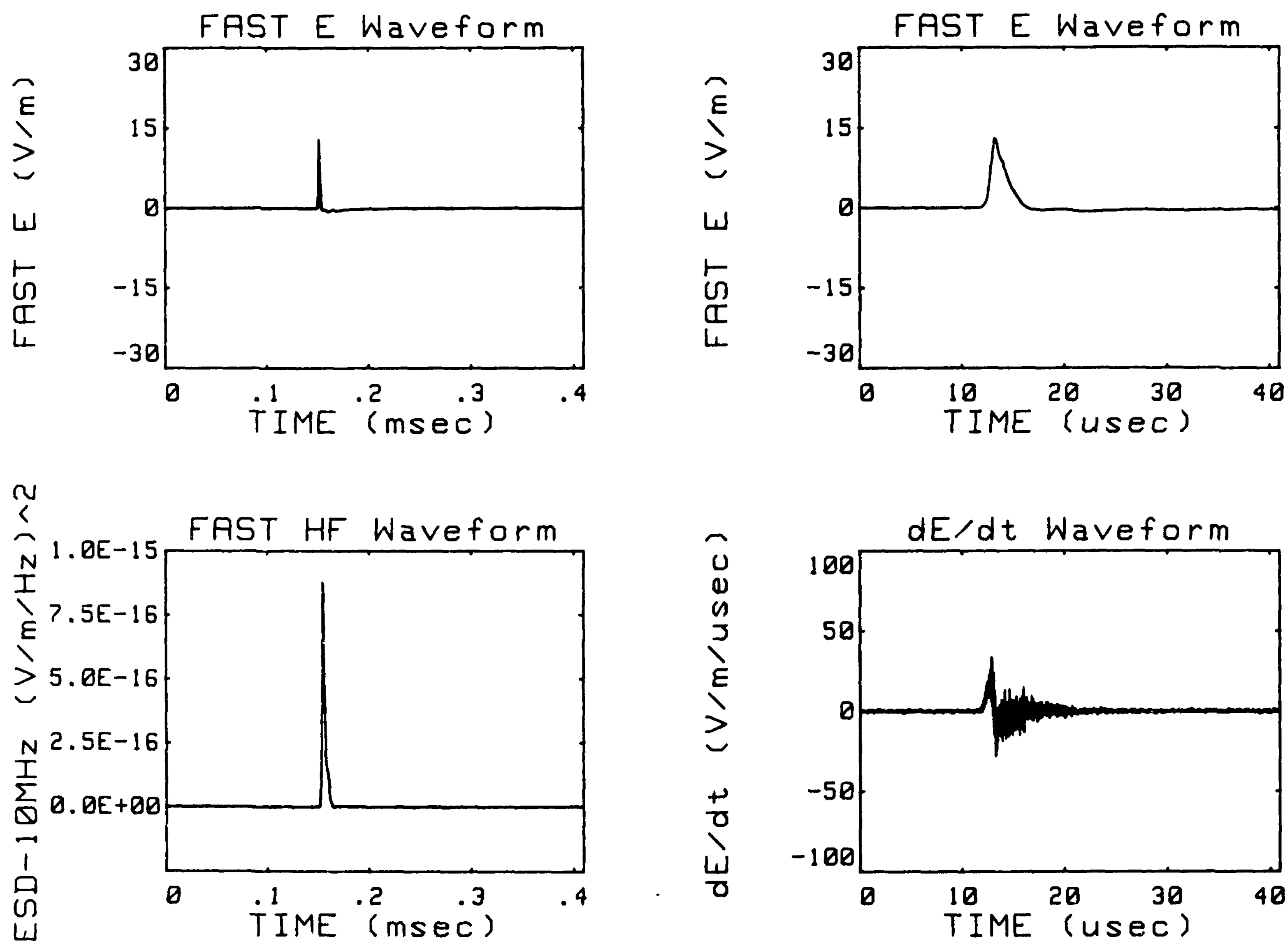

205204049.652 1985 NPBP (45.0 Km)
FAST E Waveform
FAST E (V/m)
10
5
0
-5
-10
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
10
5
0
-5
-10
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-10MHz (V/m/Hz)^2
1.0E-15
7.5E-16
5.0E-16
2.5E-16
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
30
15
0
-15
-30
0
10
20
30
40
TIME (usec)

20:40:49.259 24 Jul 1985 (45.0 Km)

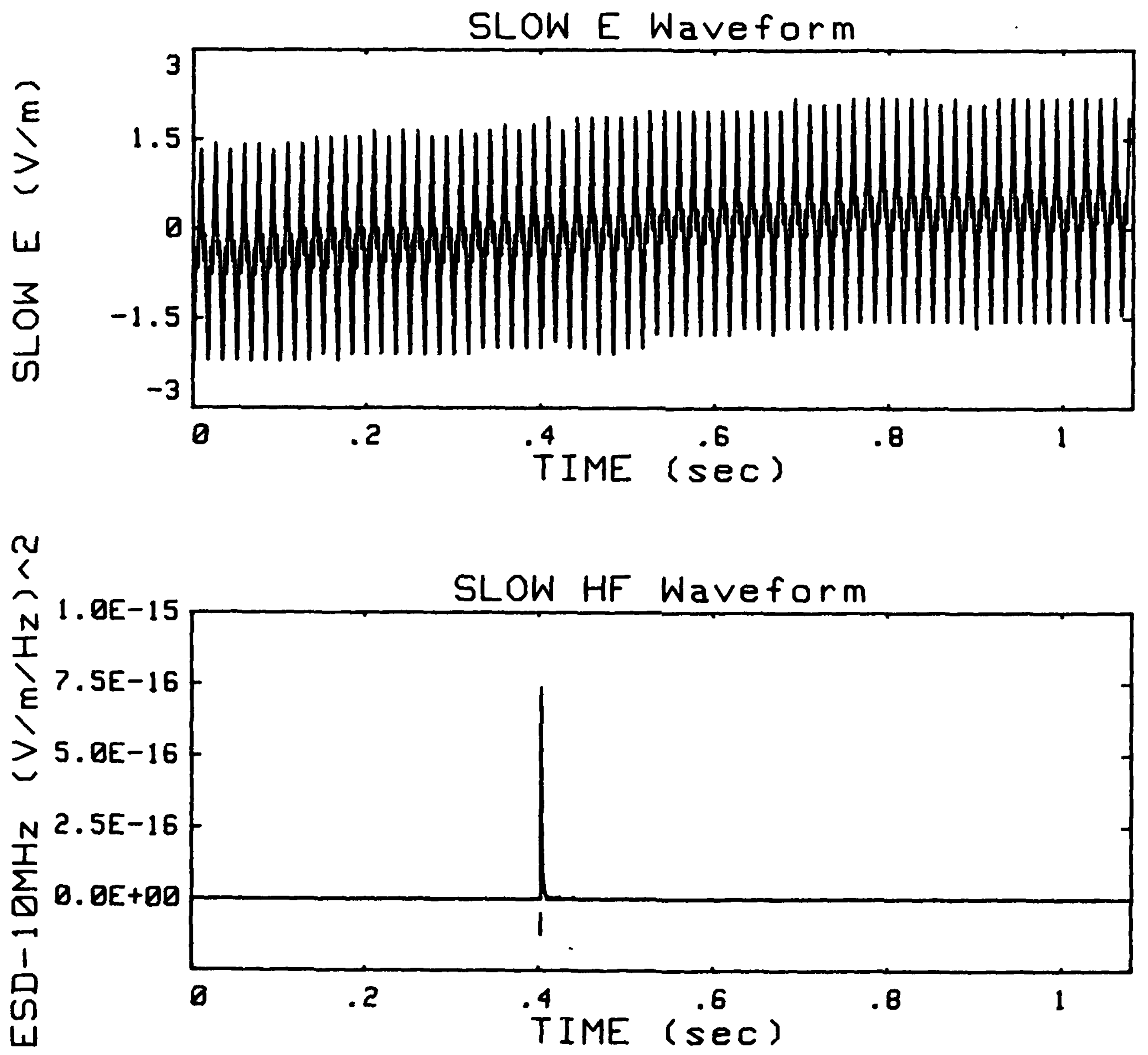




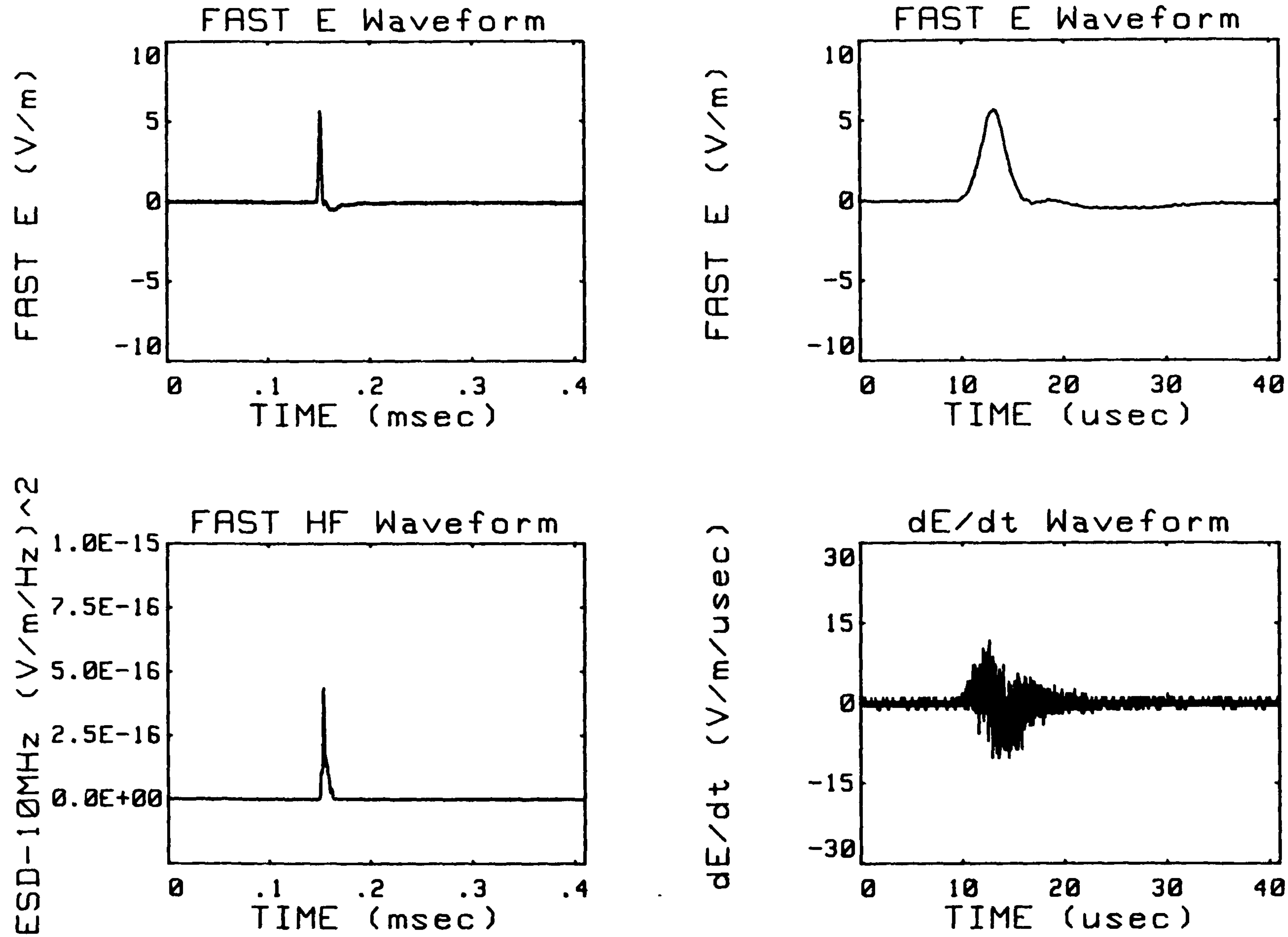
205204056.493 1985 NPBP (45.0 Km)



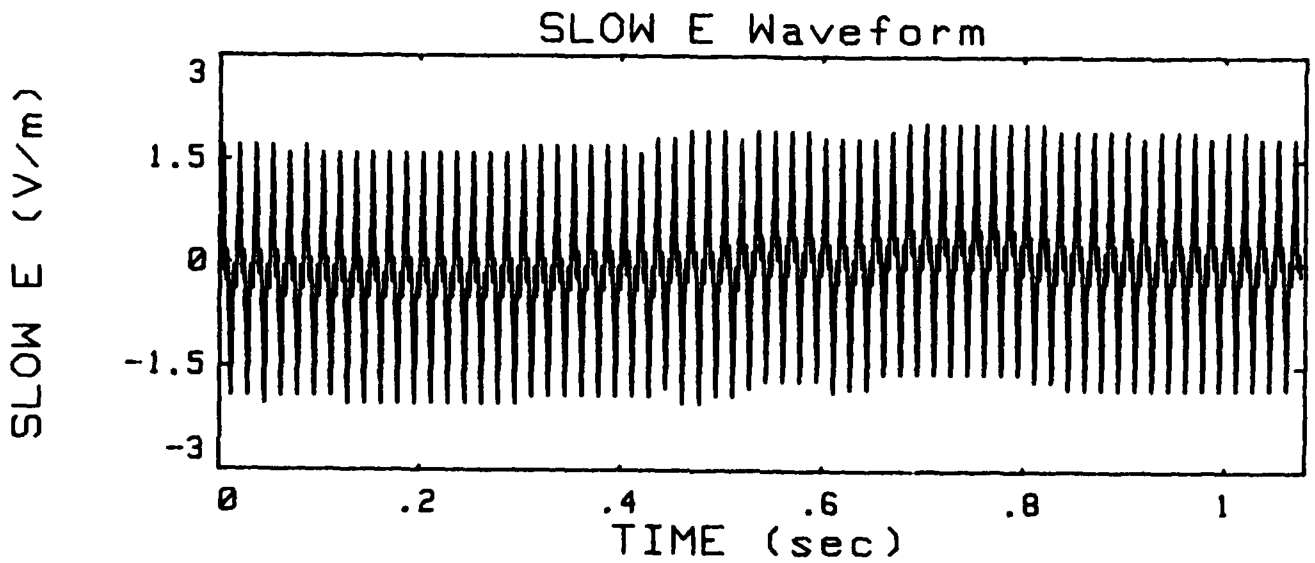
20:40:56.103 24 Jul 1985 (45.0 Km)

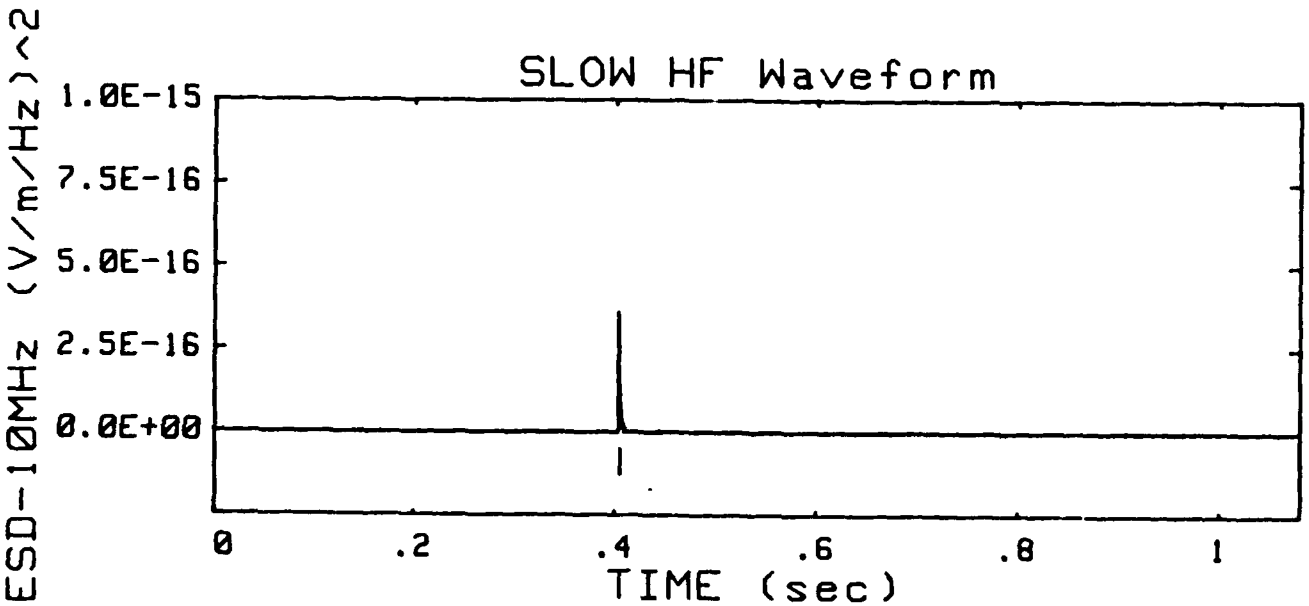


205204129.465 1985 NPBP (45.0 Km)

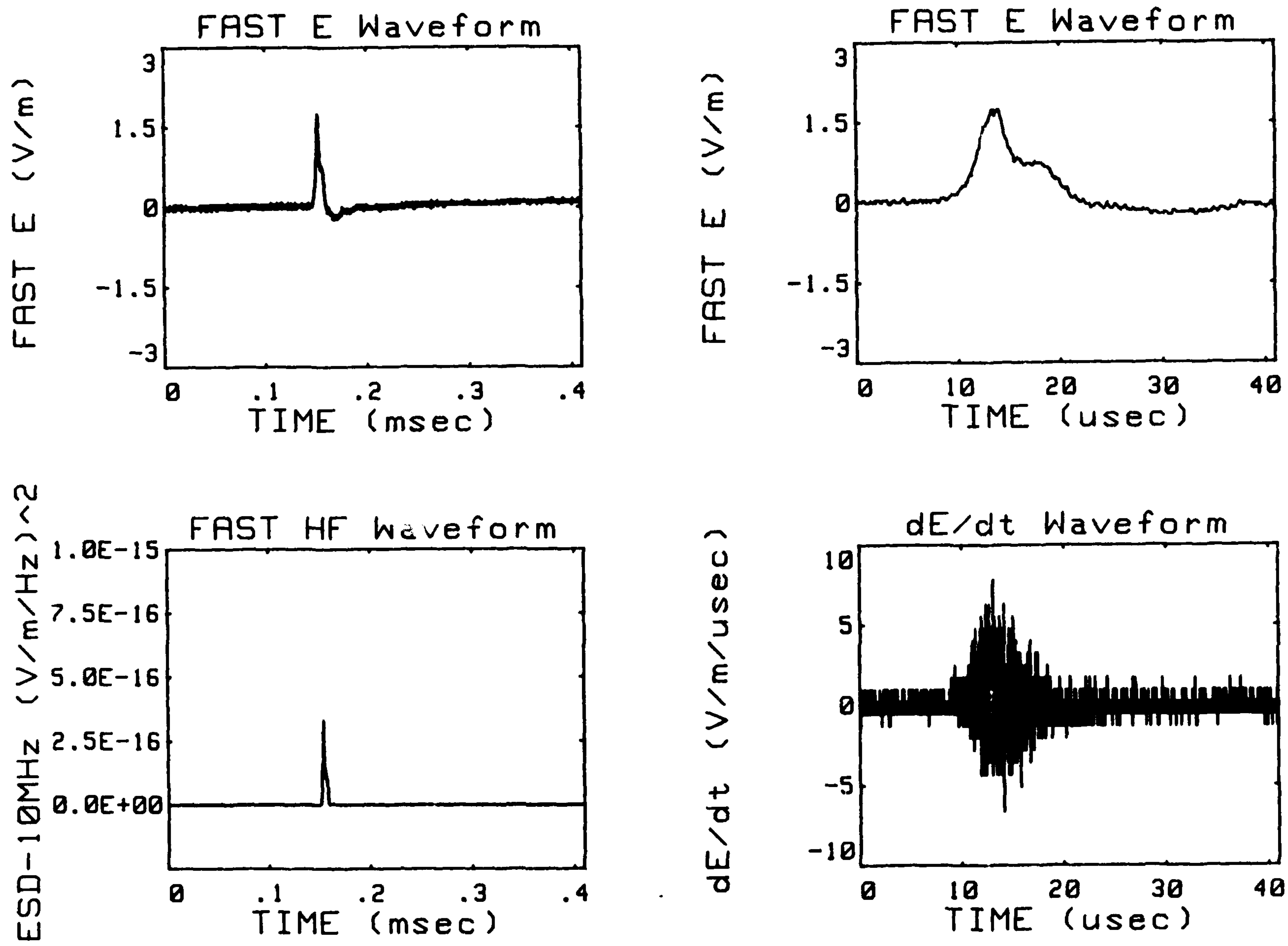


20:41:29.073 24 Jul 1985 (45.0 Km)

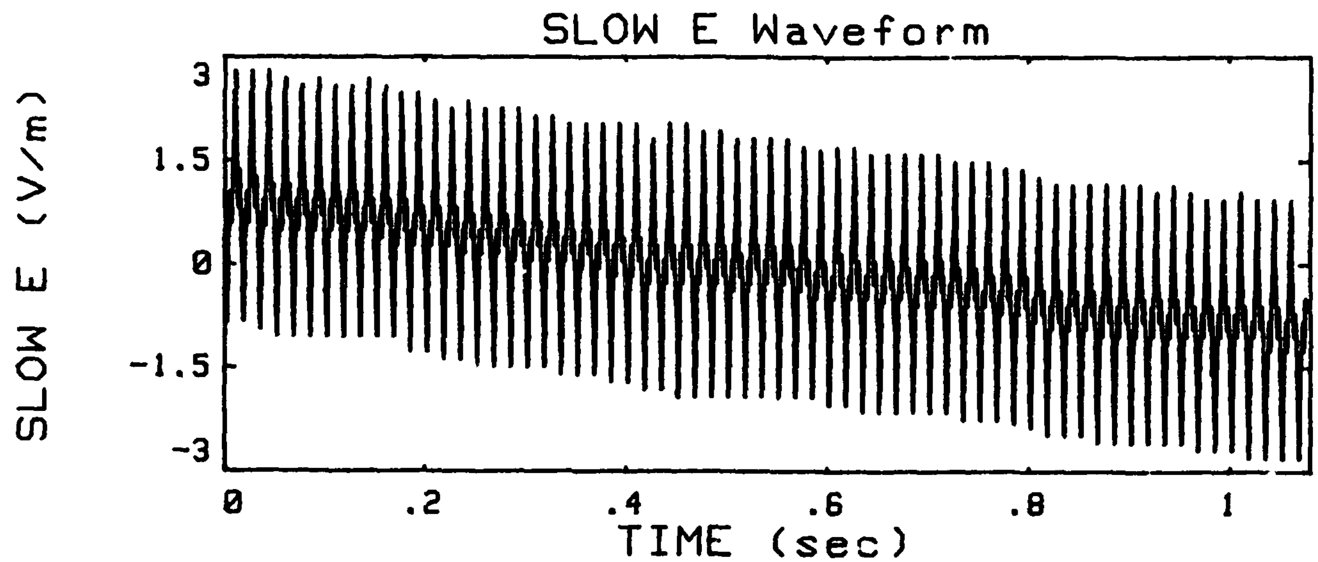


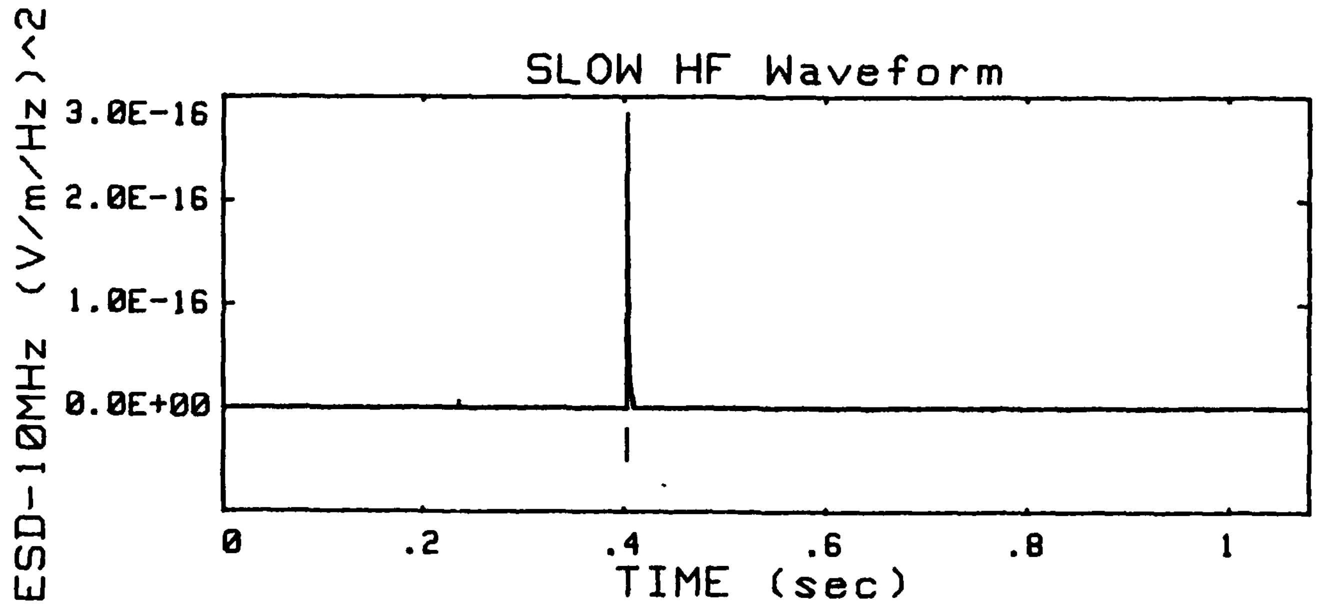


205204144.372 1985 NPBP (45.0 Km)

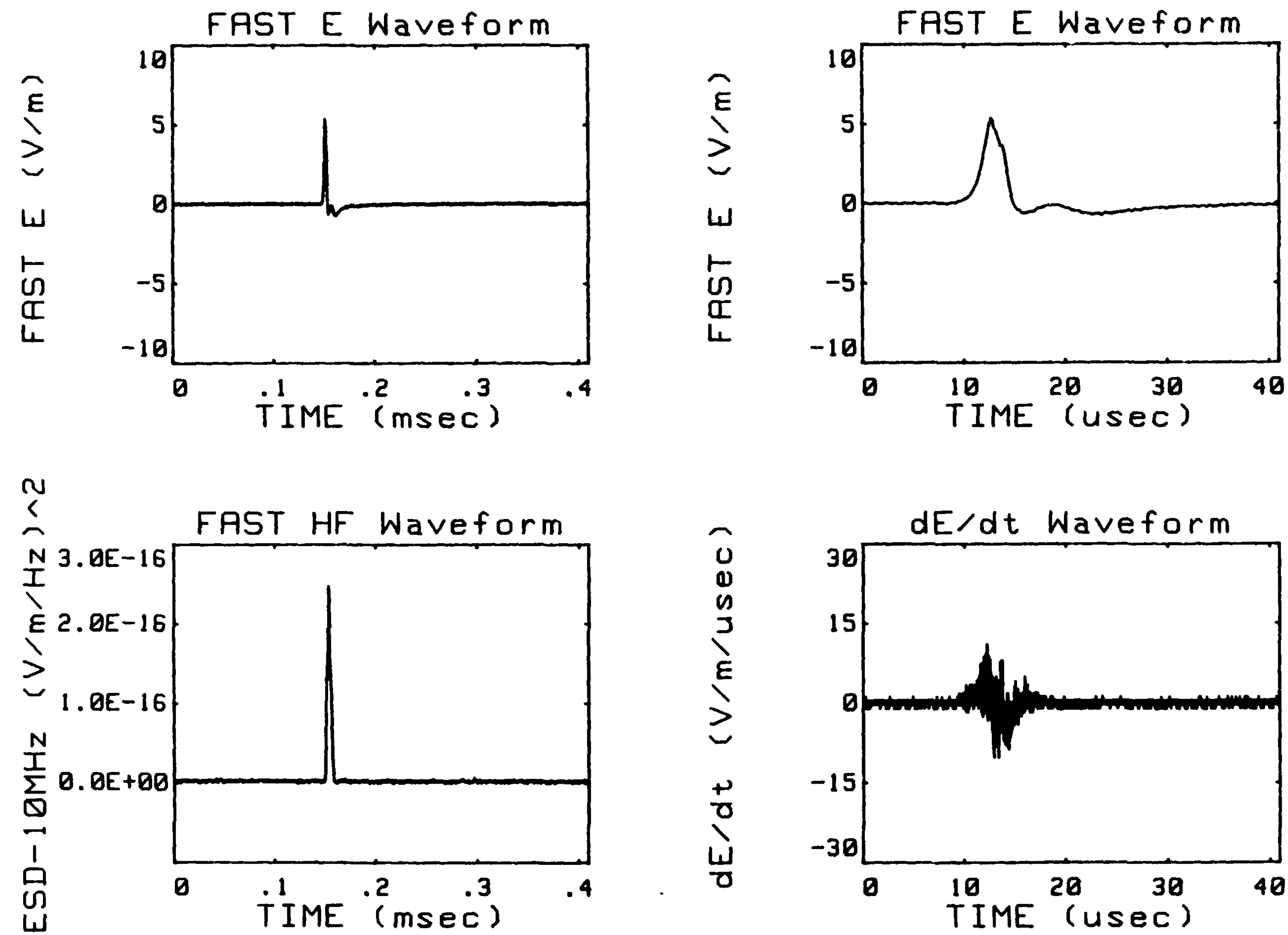


20:41:43.982 24 Jul 1985 (45.0 Km)

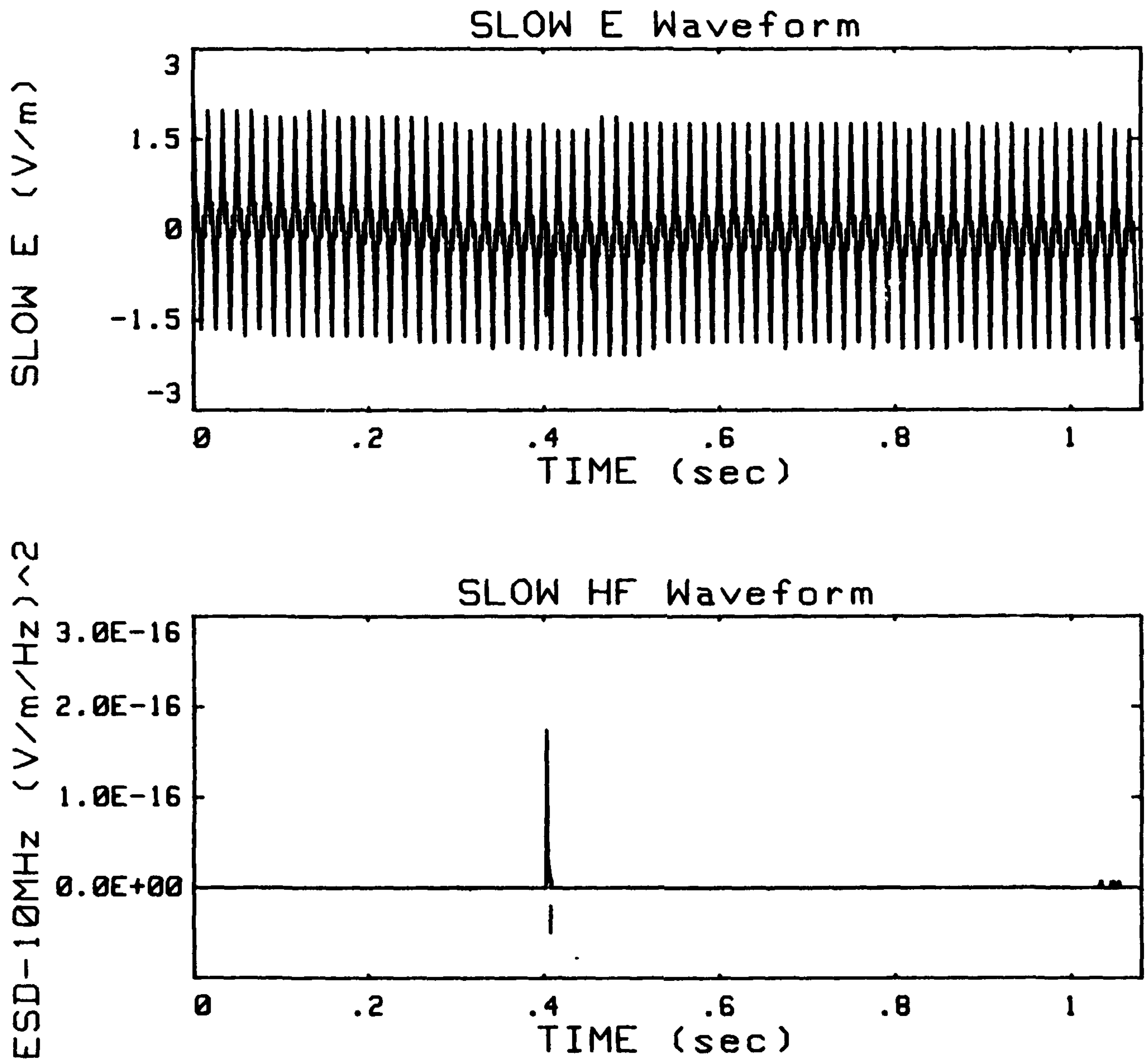




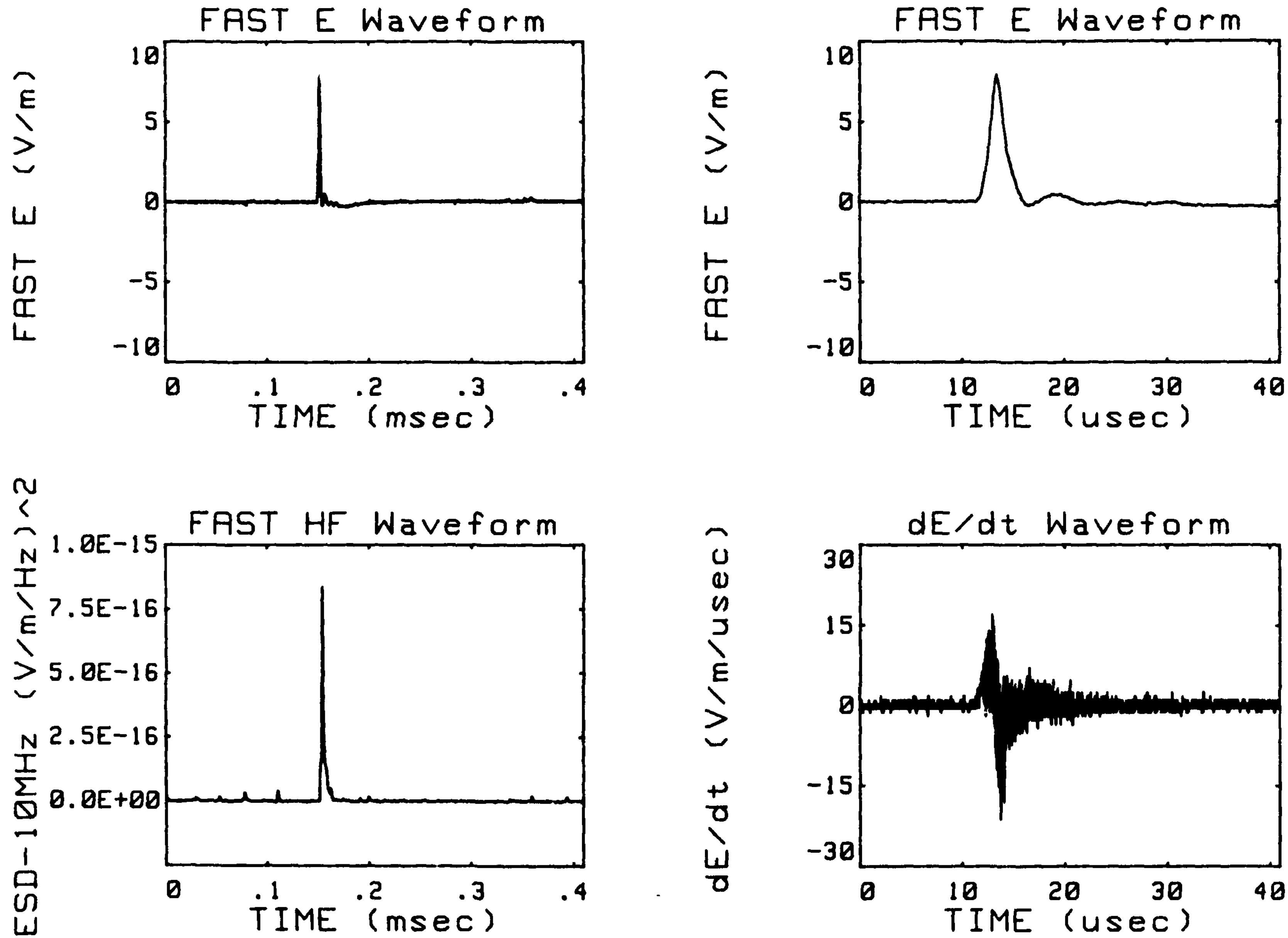
205204218.614 1985 NPBP (45.0 Km)



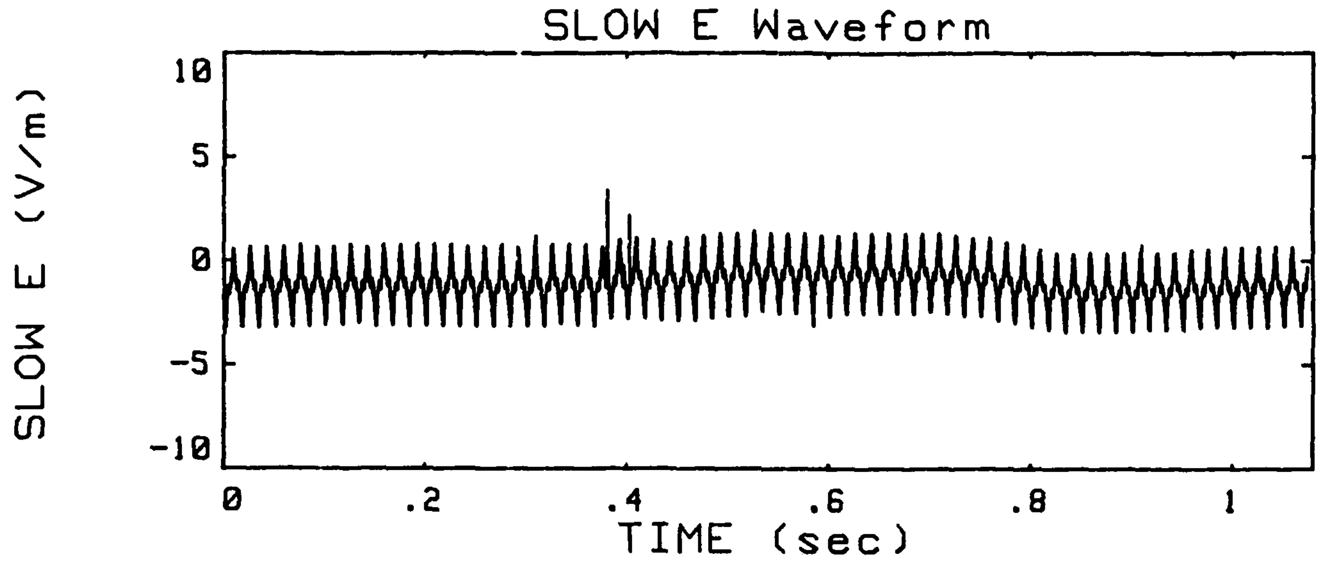
20:42:18.219 24 Jul 1985 (45.0 Km)

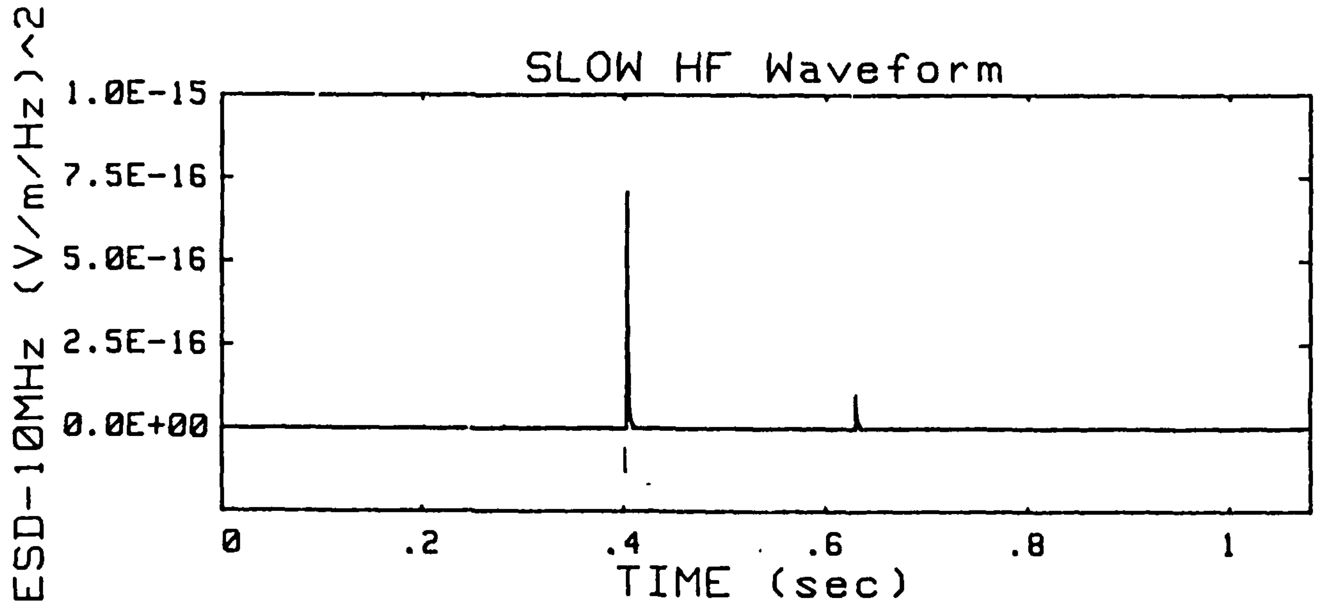


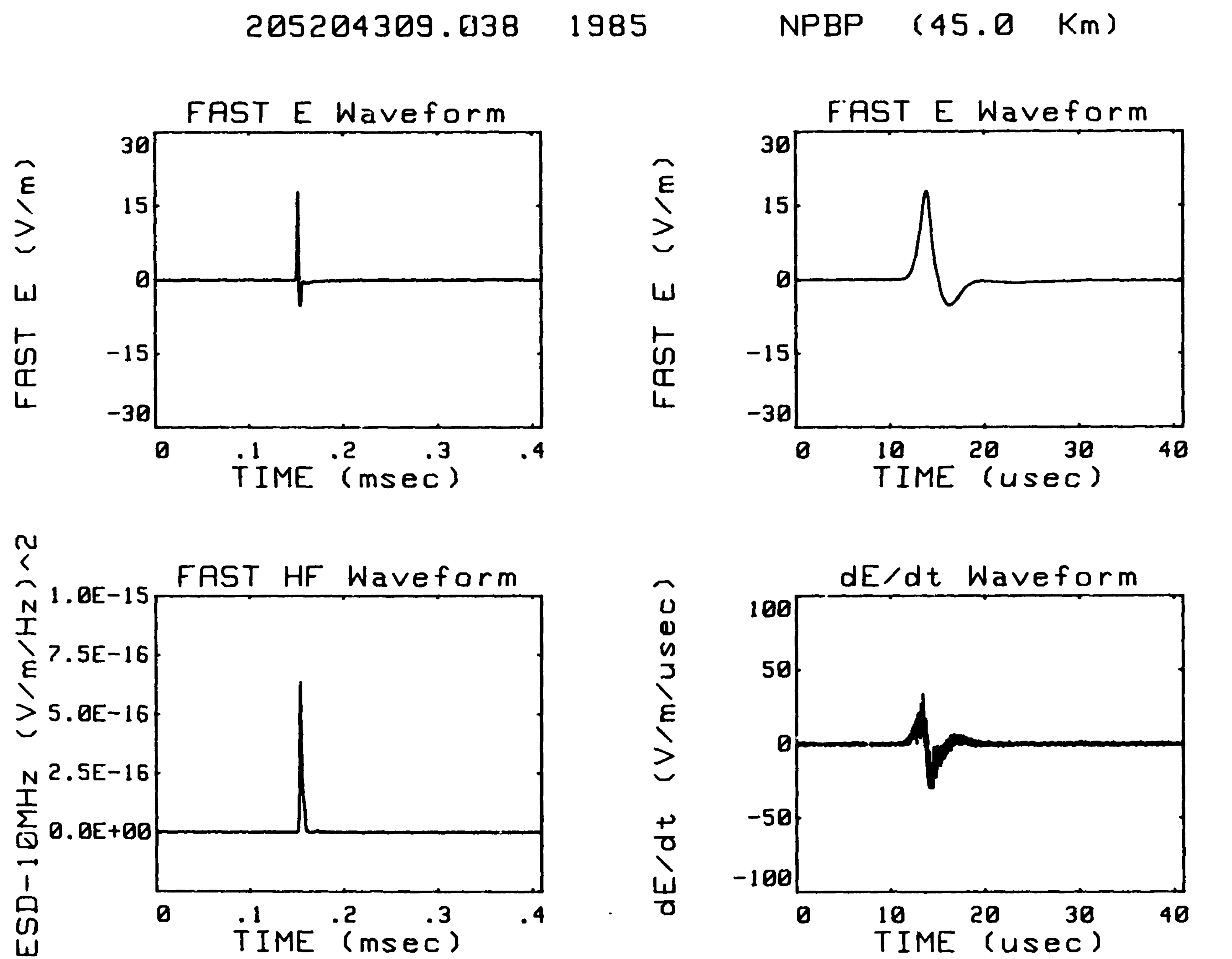
205204259.535 1985 NPBP (45.0 Km)



20:42:59.139 24 Jul 1985 (45.0 Km)

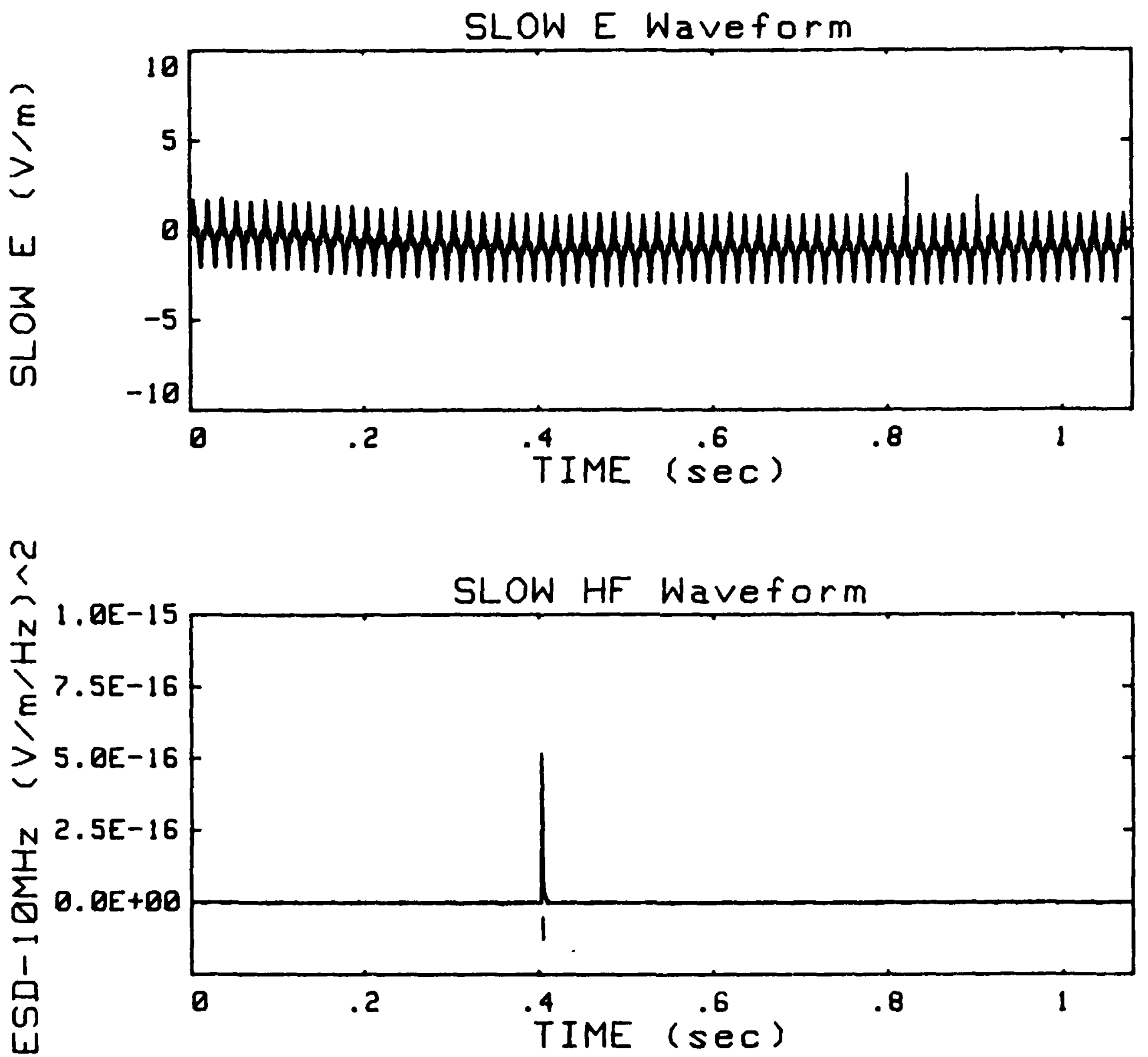




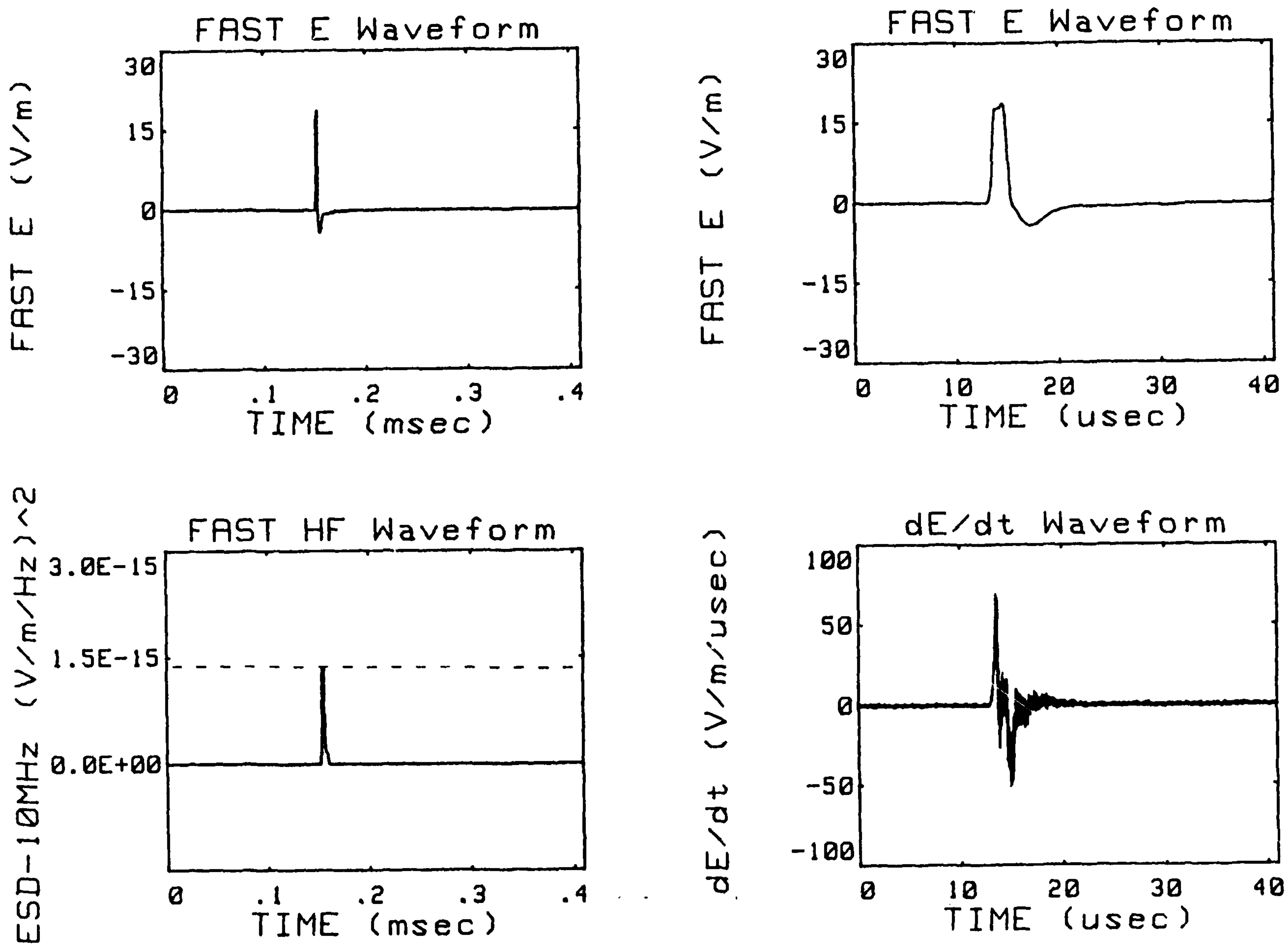


205204309.038 1985 NPBP (45.0 Km)
FAST E Waveform
FAST E (V/m)
30
15
0
-15
-30
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
30
15
0
-15
-30
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-10MHz (V/m/Hz)^2
1.0E-15
7.5E-16
5.0E-16
2.5E-16
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
100
50
0
-50
-100
0
10
20
30
40
TIME (usec)

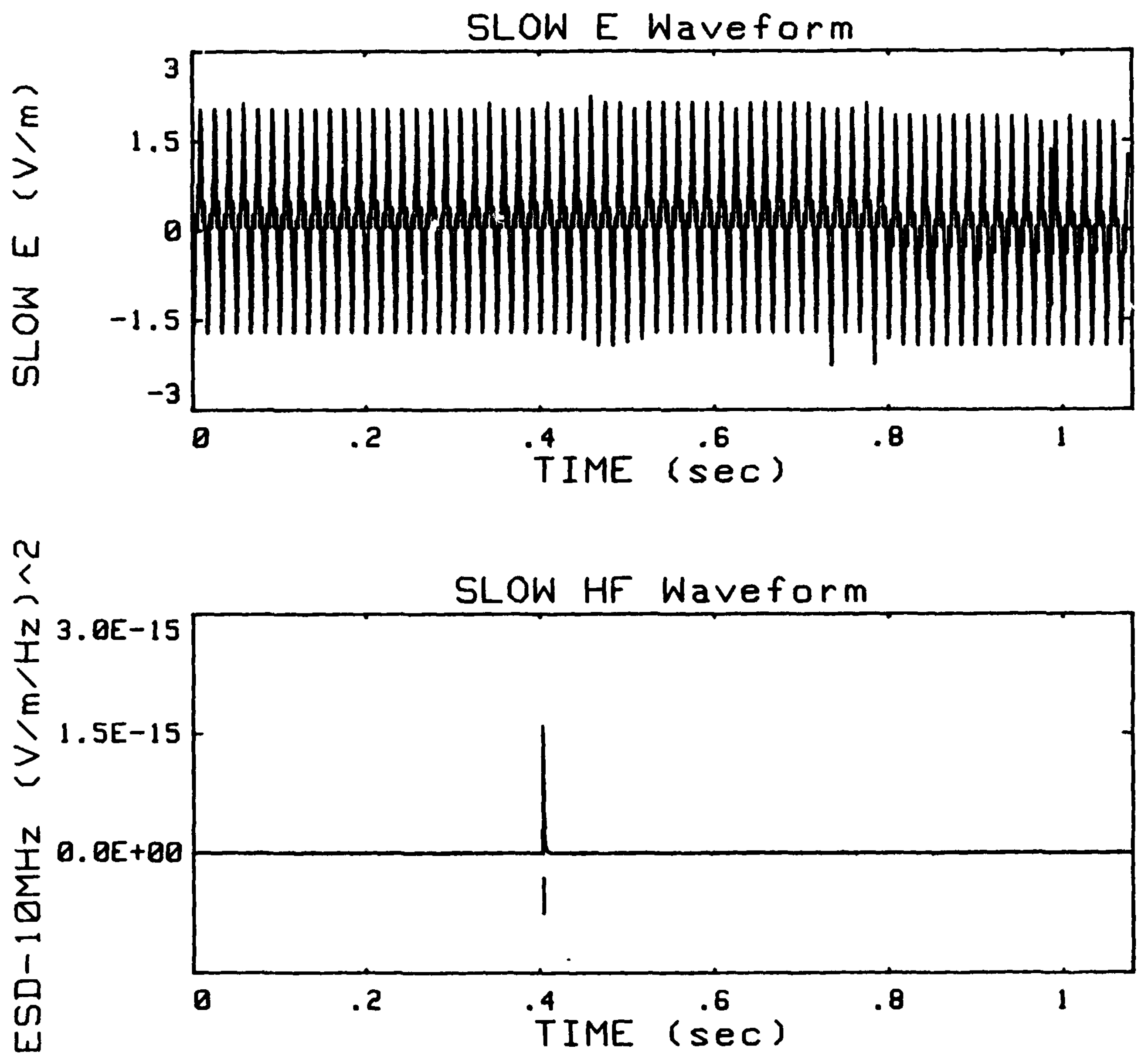
20:43:08.646 24 Jul 1985 (45.0 Km)



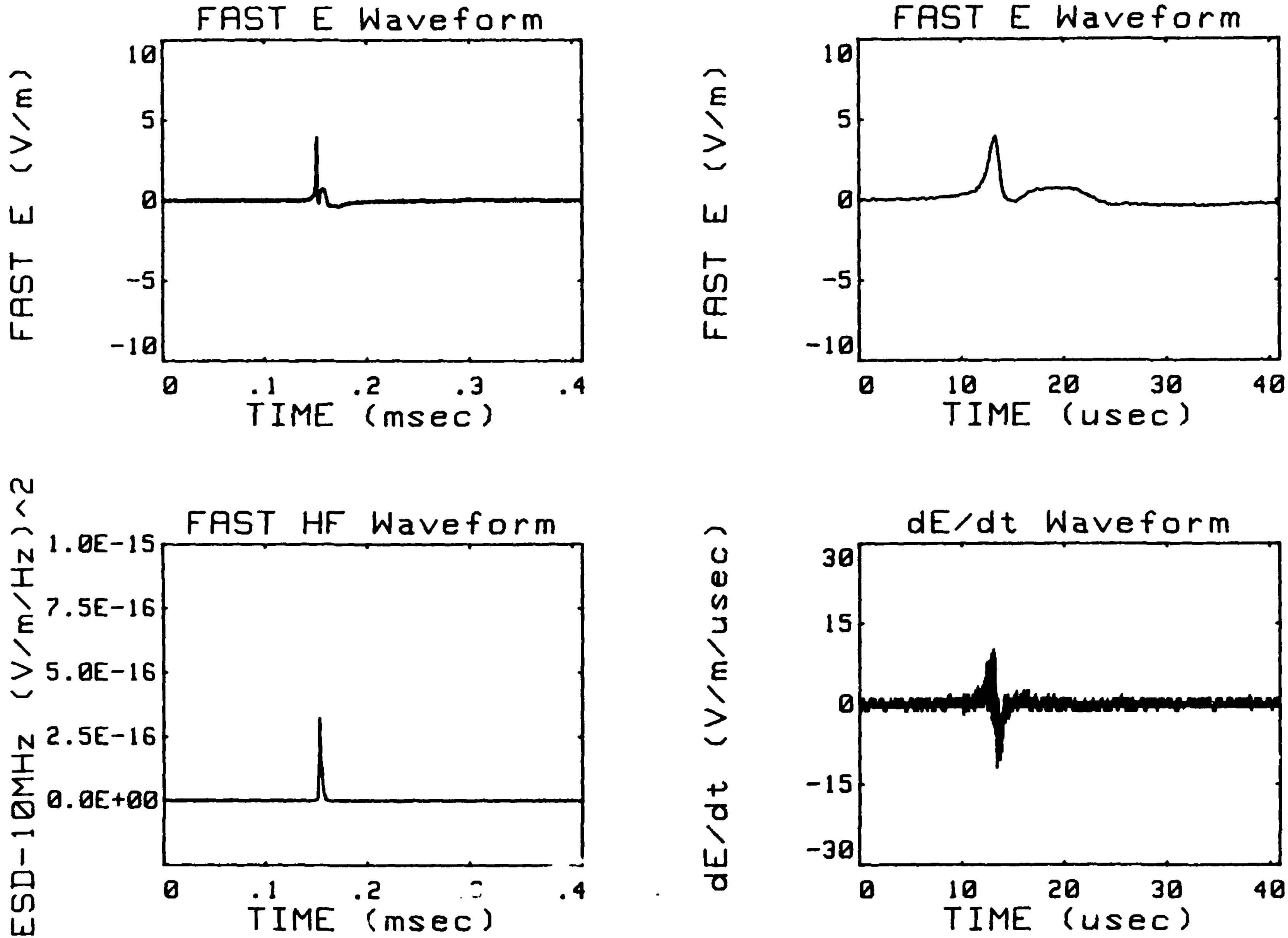
205204324.797 1985 NPBP (45.0 Km)



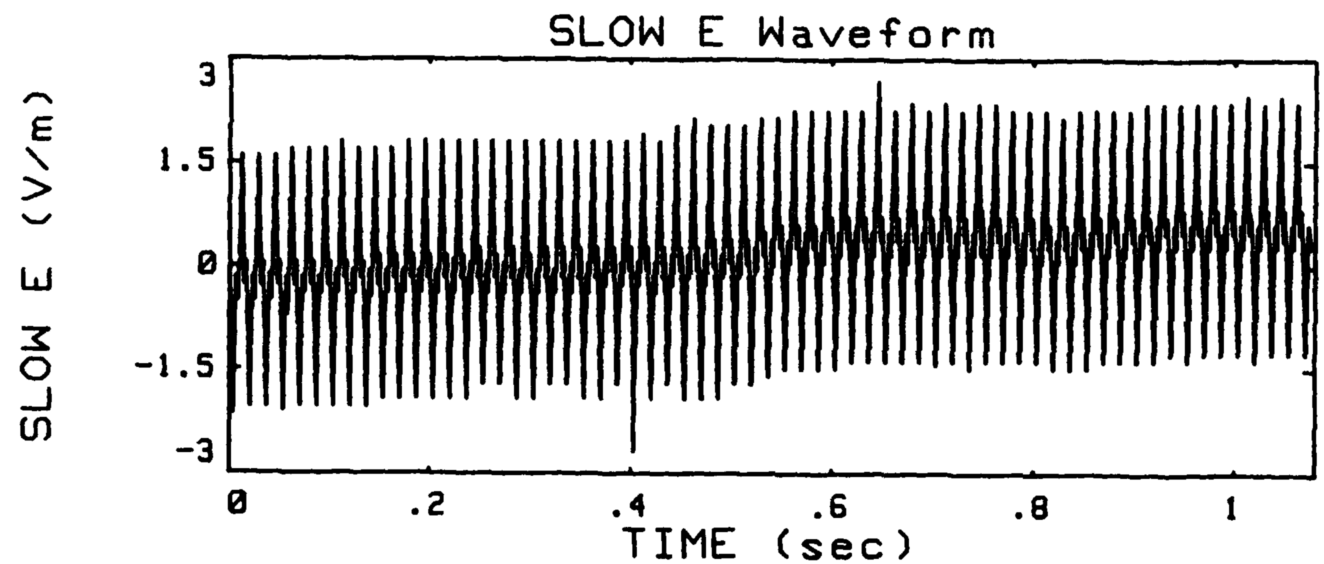
20:43:24.406 24 Jul 1985 (45.0 Km)

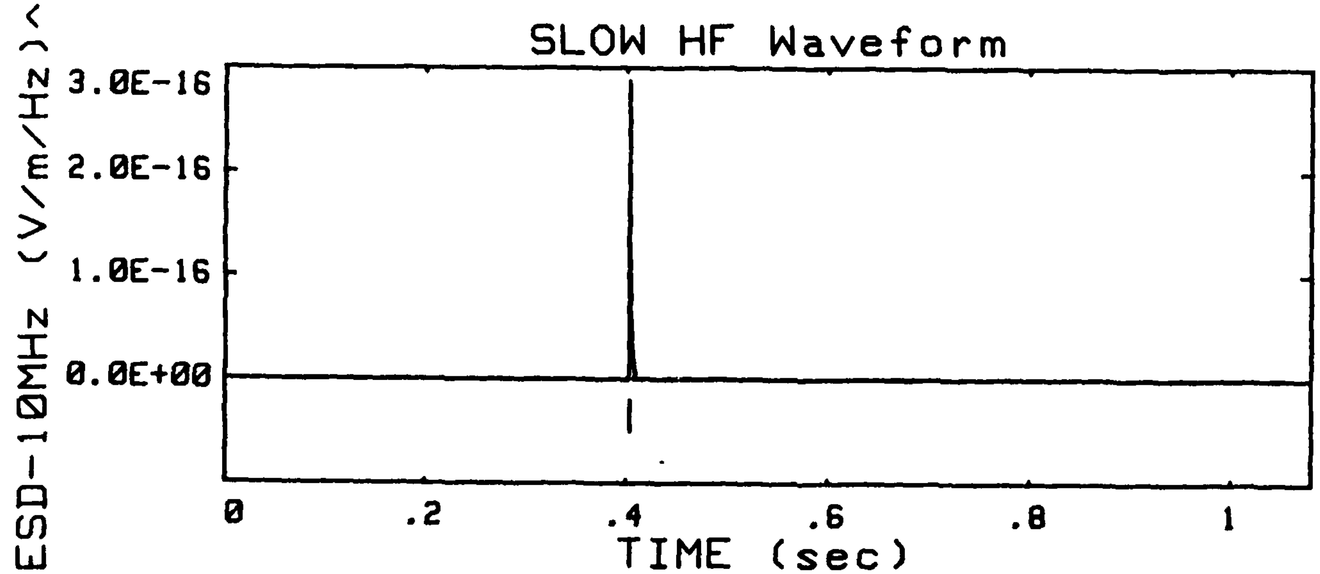


205204336.194 1985 NPBP (45.0 Km)

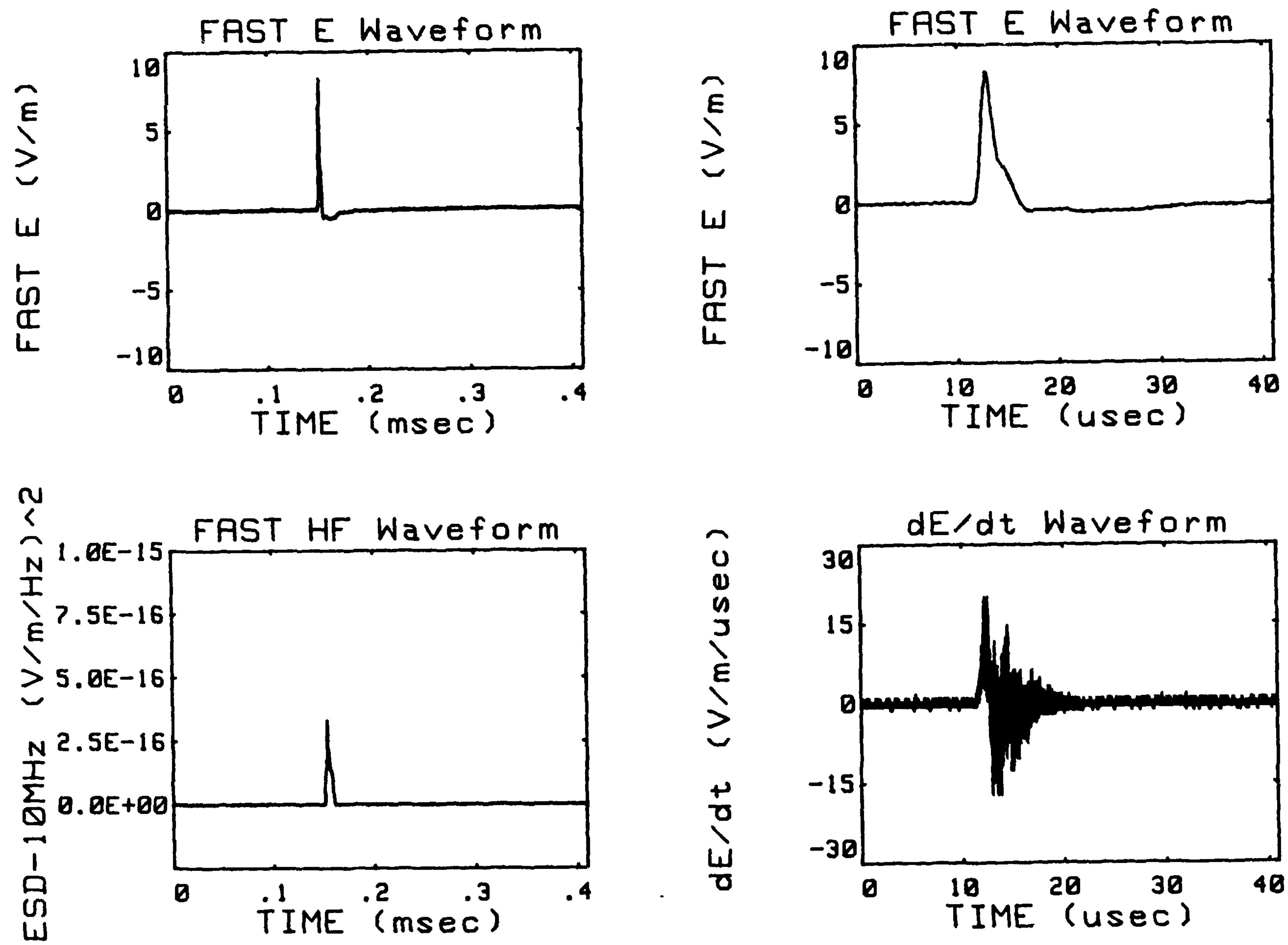


20:43:35.803 24 Jul 1985 (45.0 Km)

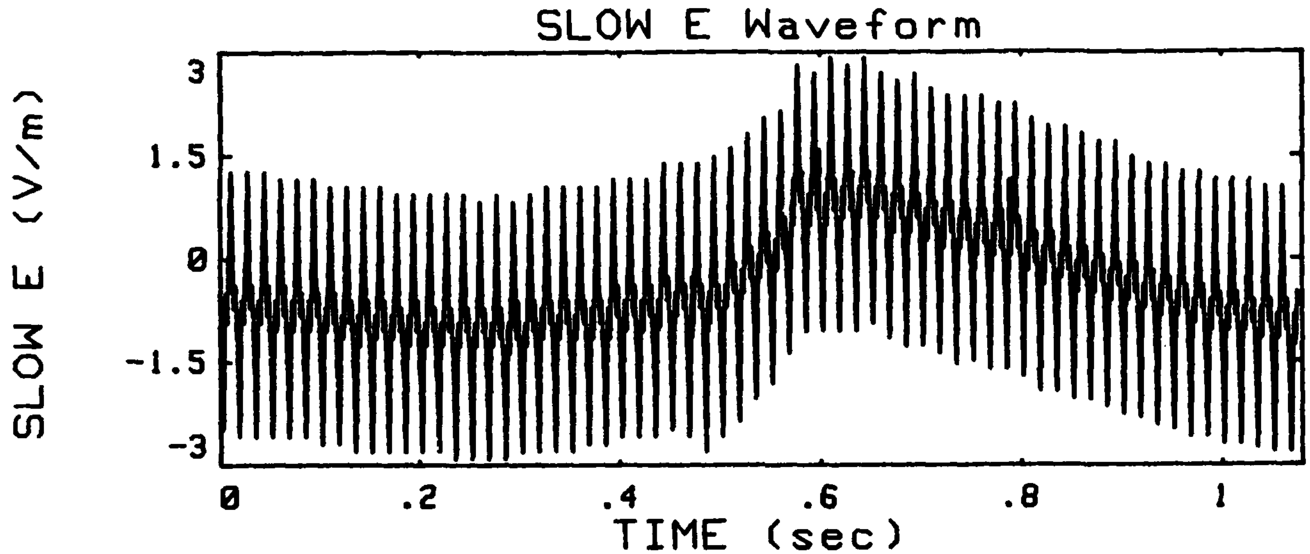


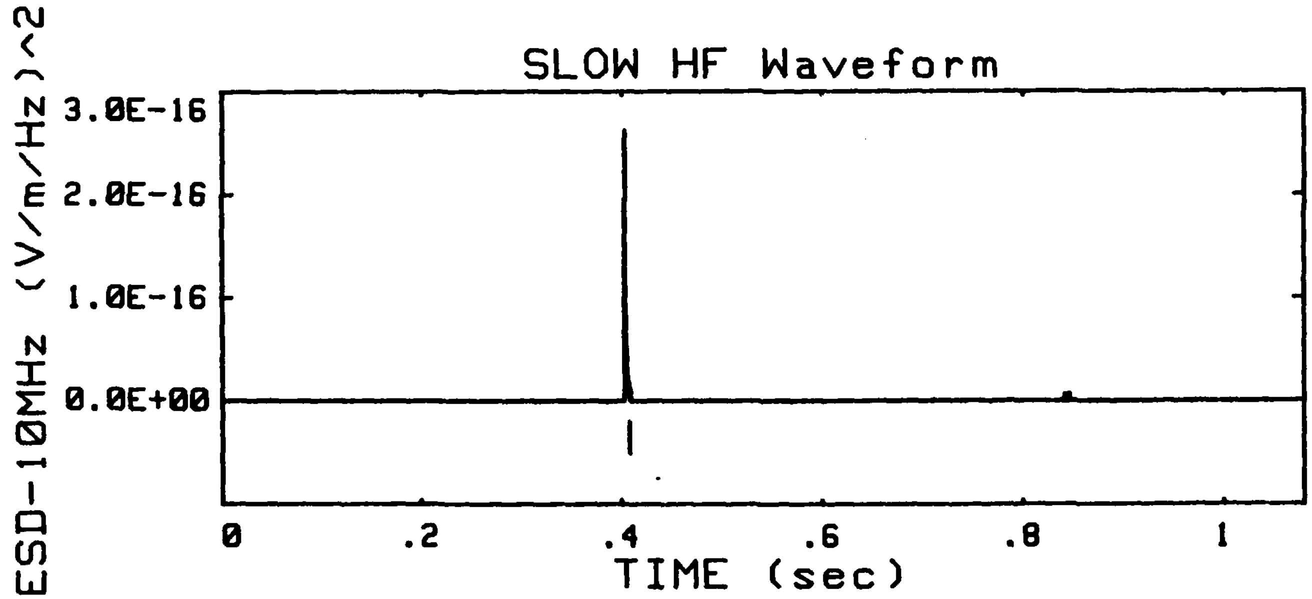


205204438.273 1985 NPBP (45.0 Km)

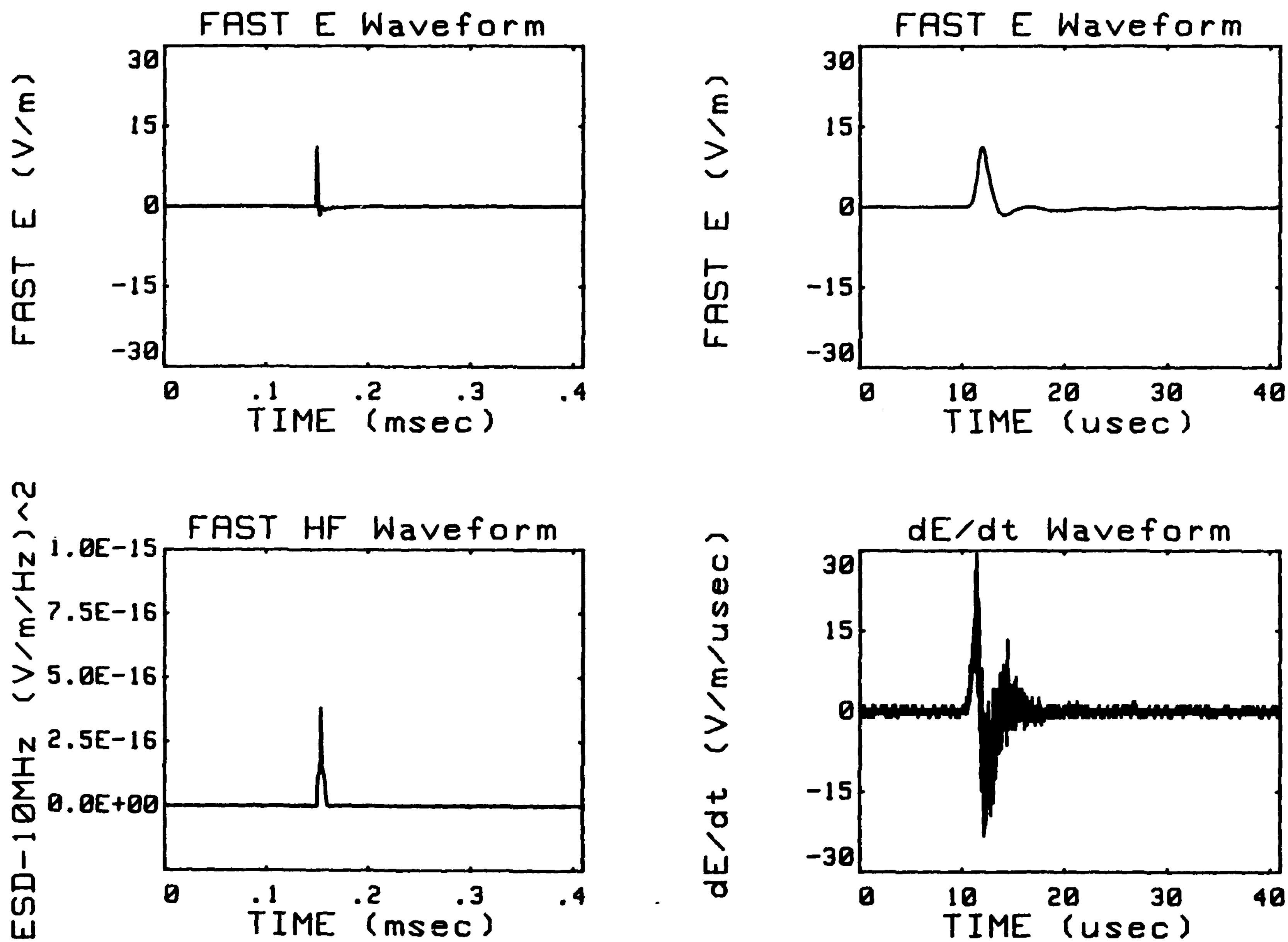


20:44:37.878 24 Jul 1985 (45.0 Km)

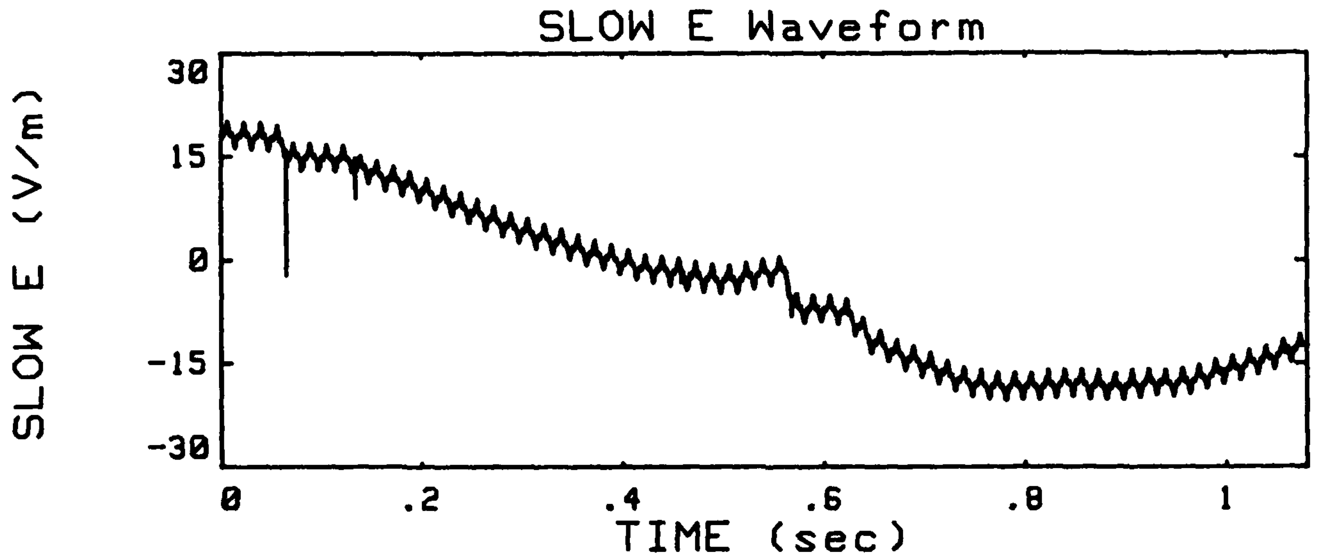


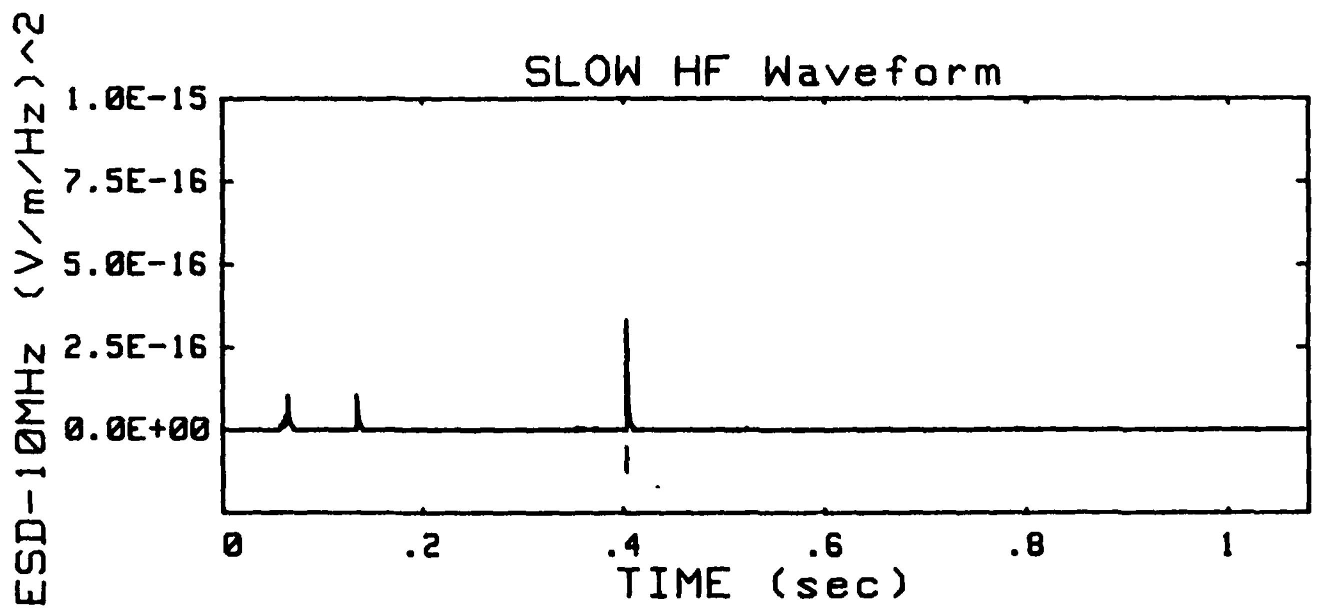


205204610.539 1985 NPBP (45.0 Km)

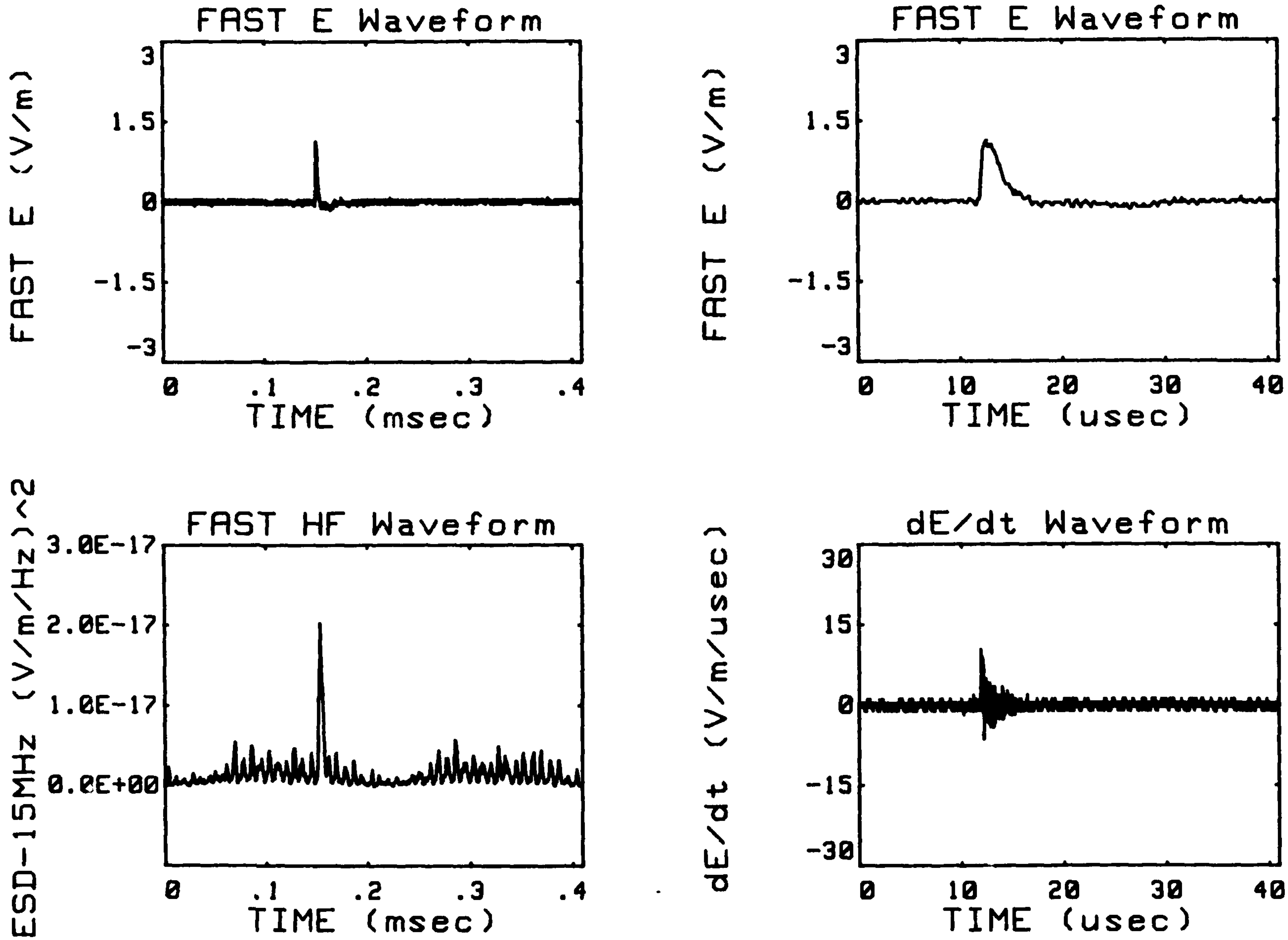


20:46:10.149 24 Jul 1985 (45.0 Km)

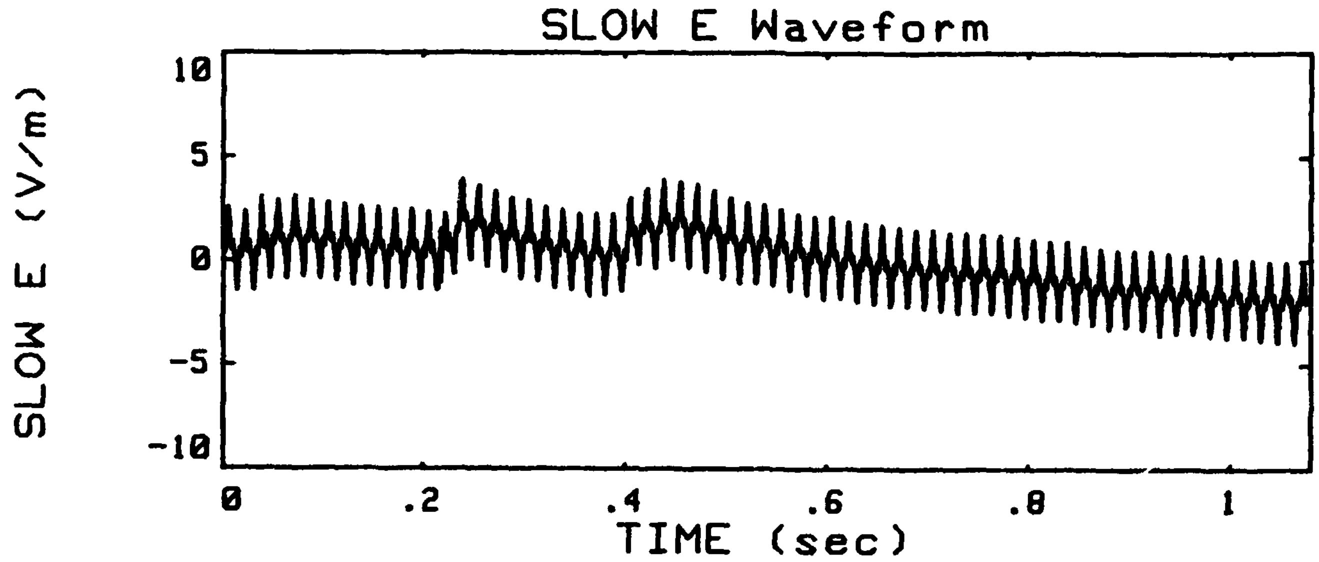


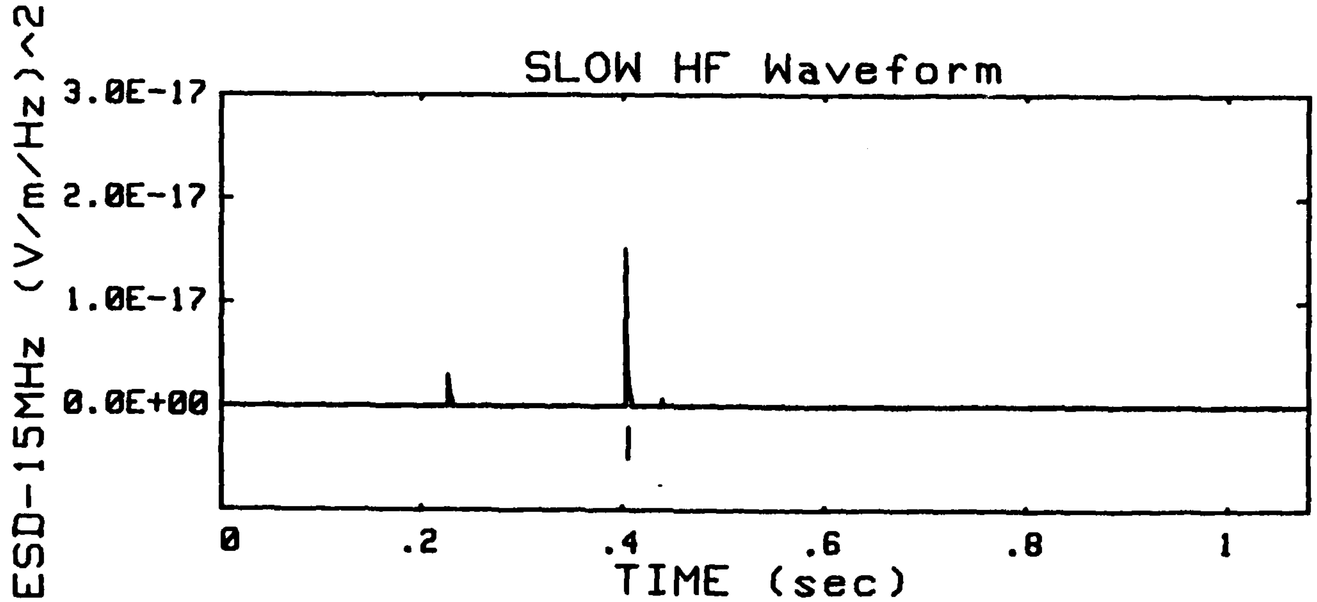


205204906.133 1985 NPBP (45.0 Km)



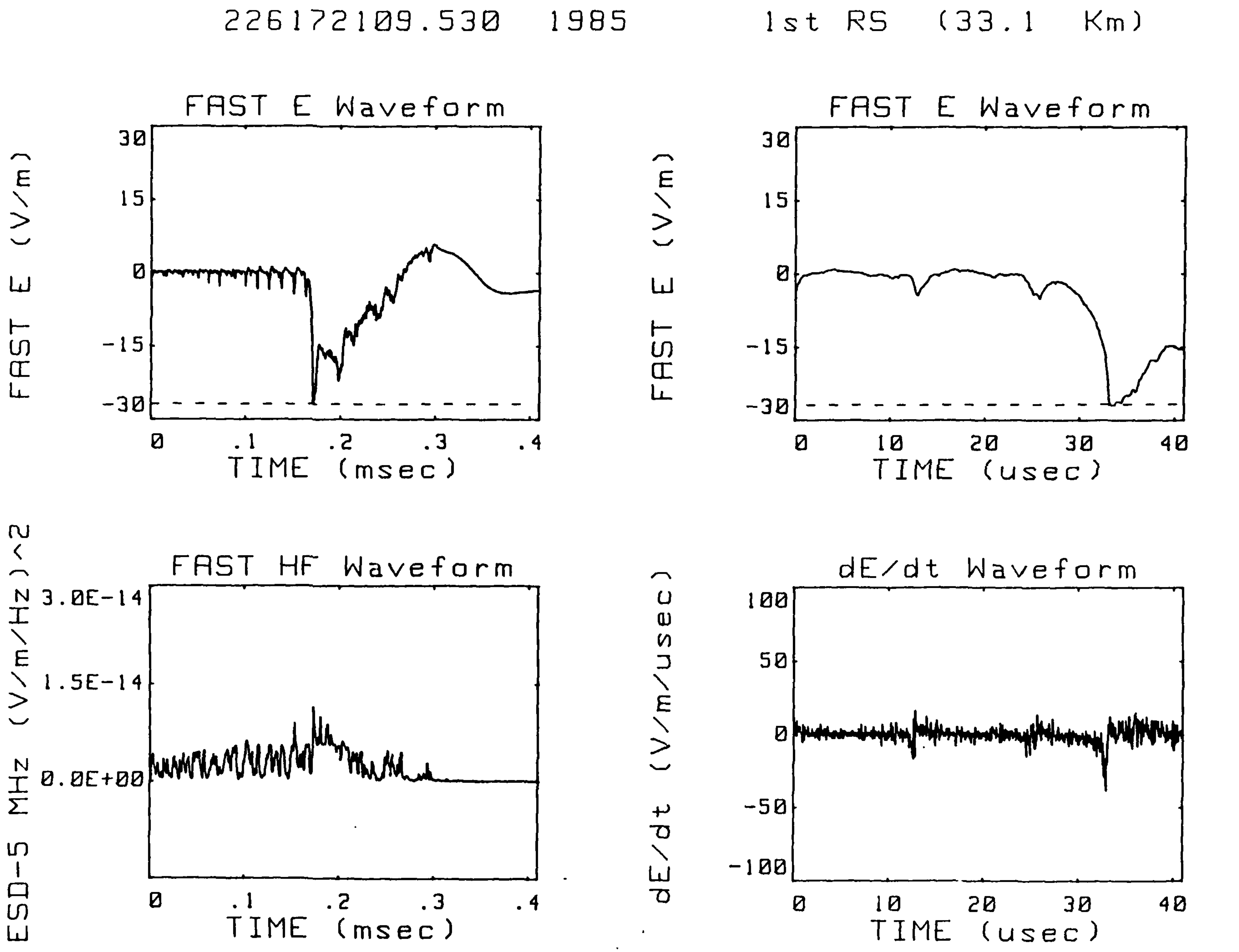
20:49:05.740 24 Jul 1985 (45.0 Km)





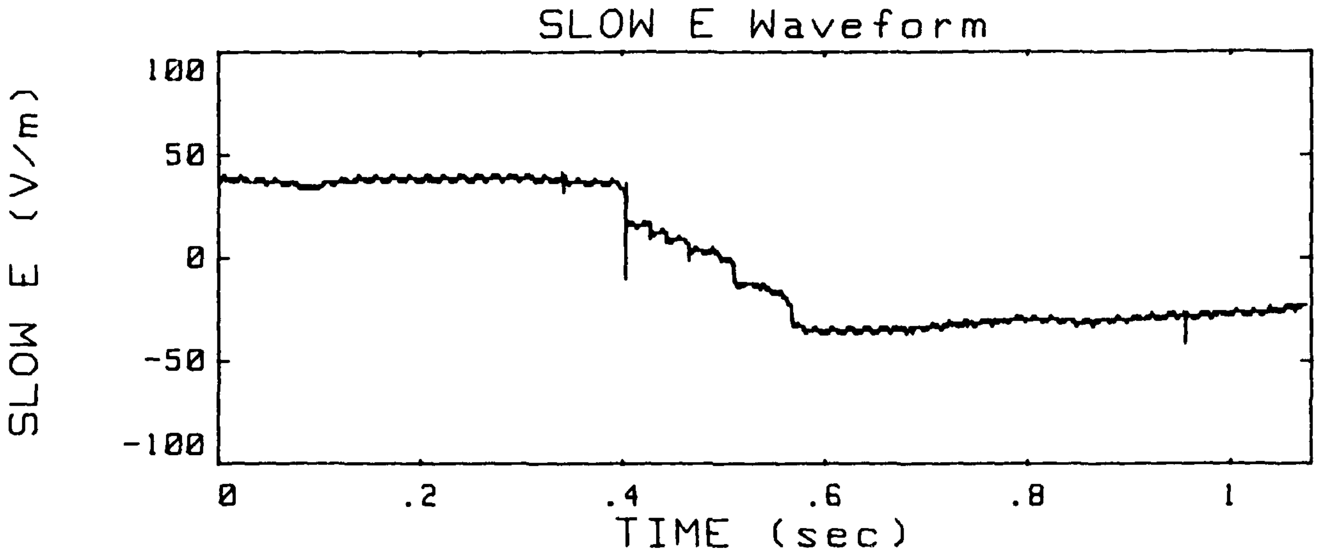
APPENDIX B

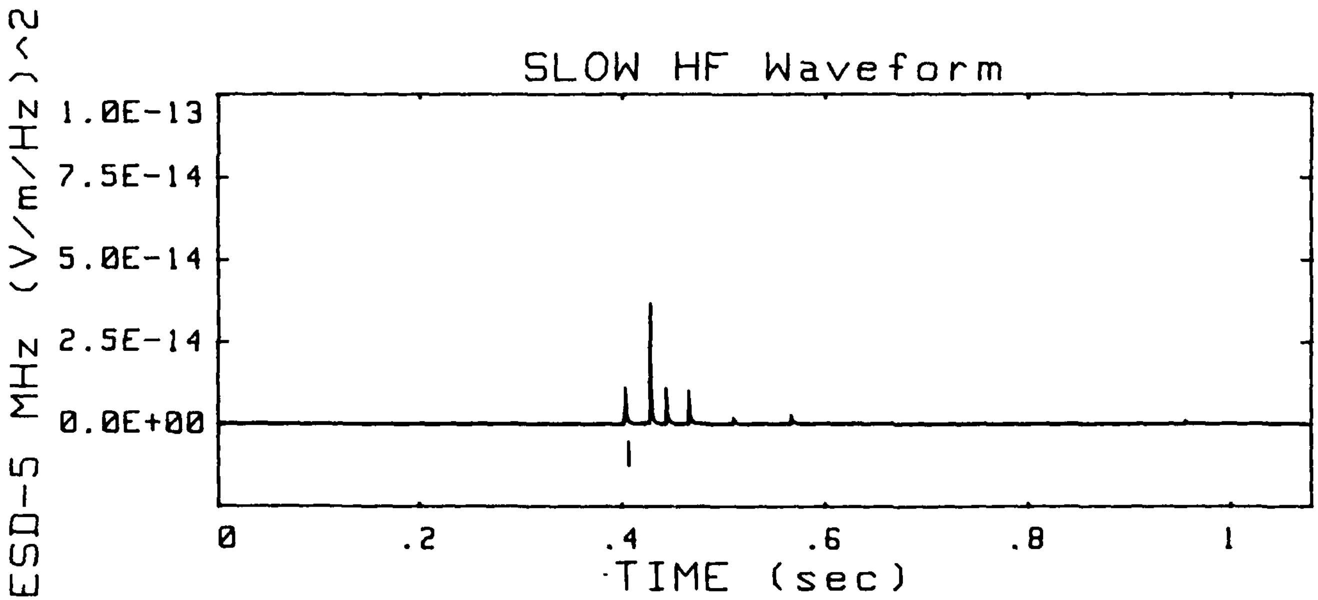
August 14 Data Plots



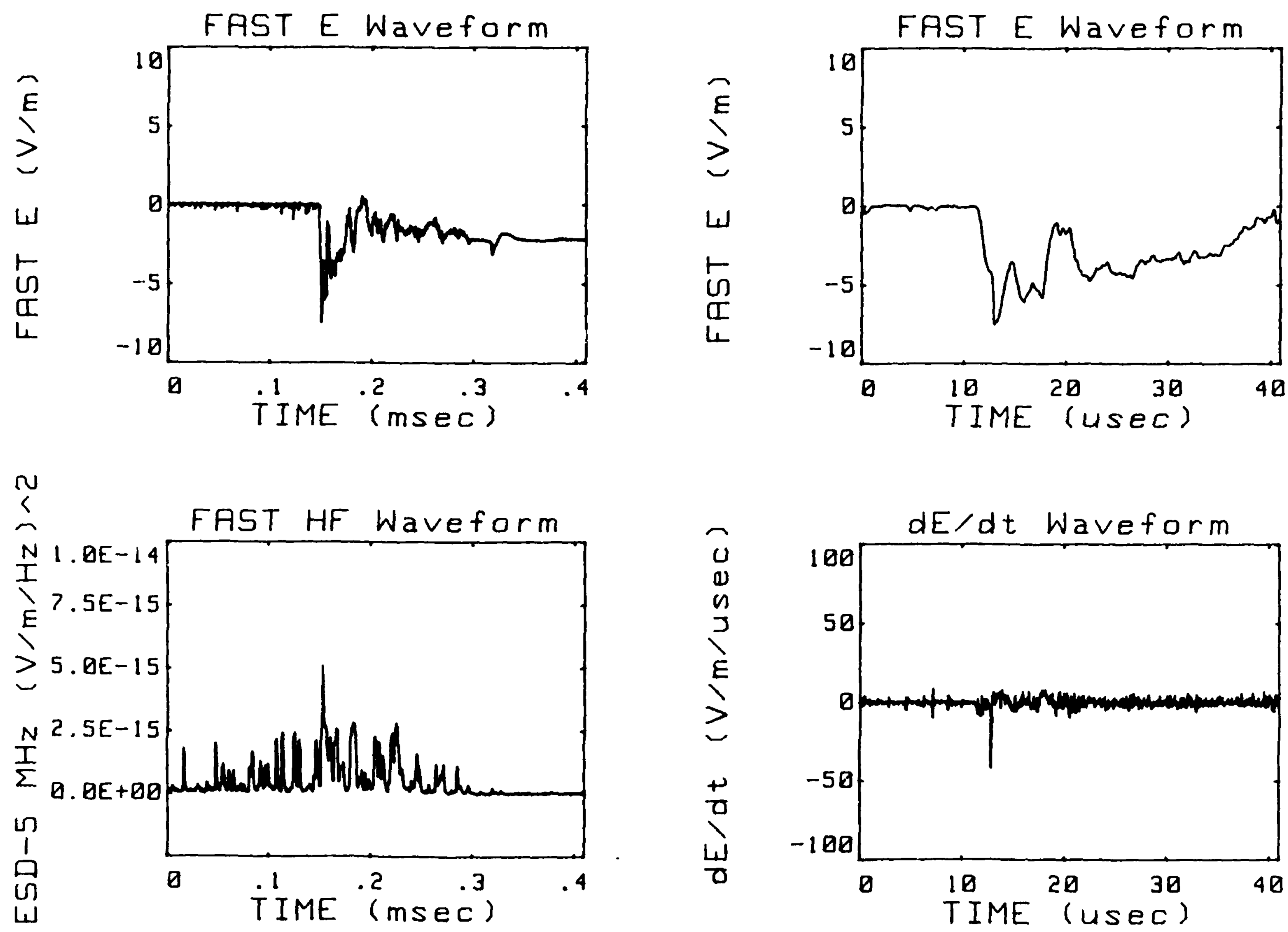
226172109.530 1985 1st RS (33.1 Km)
FAST E Waveform
FAST E (V/m)
30
15
0
-15
-30
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
30
15
0
-15
-30
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
3.0E-14
1.5E-14
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
100
50
0
-50
-100
0
10
20
30
40
TIME (usec)

17:21:09.136 14 Aug 1985 (33.1 Km)

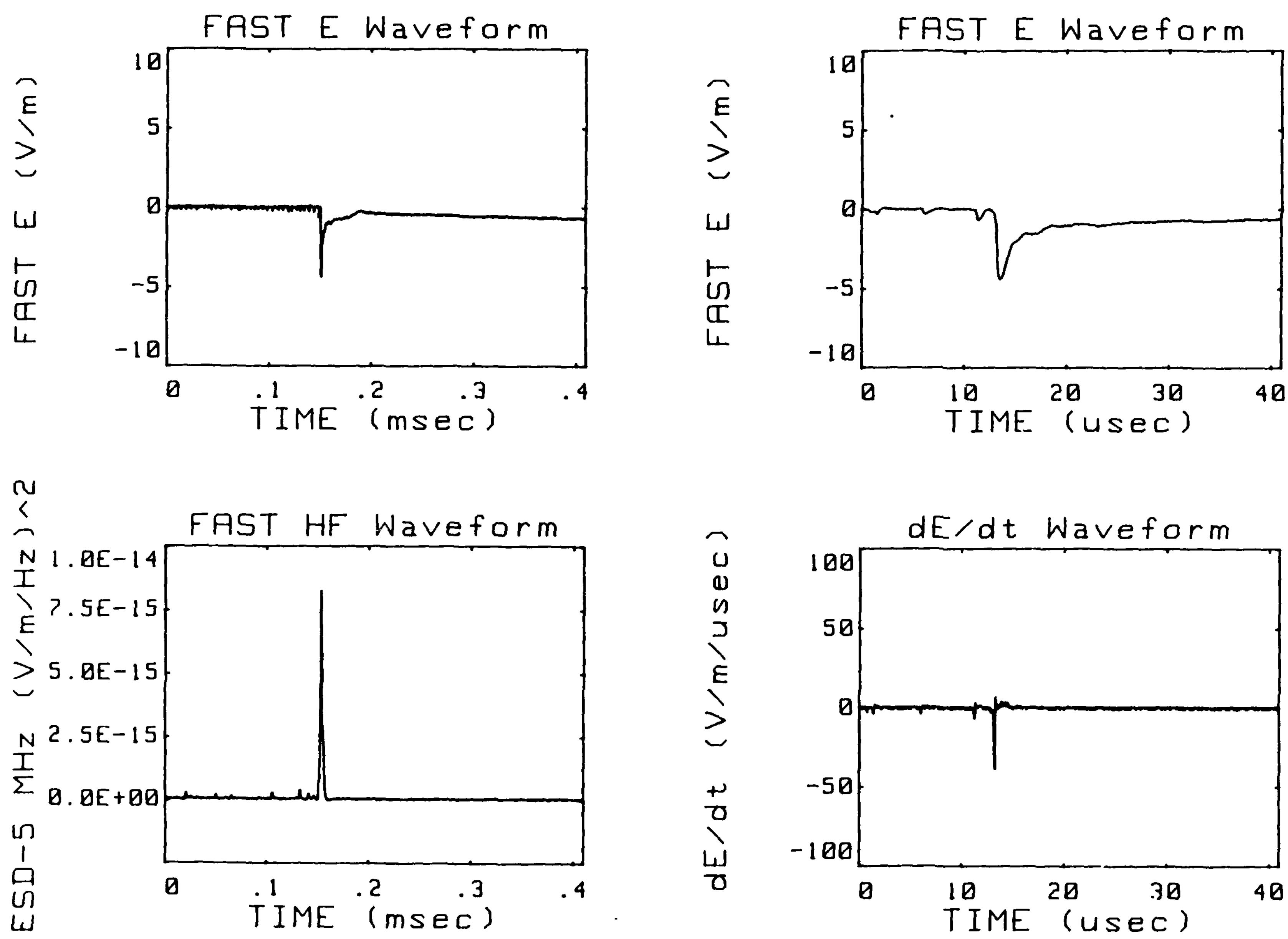


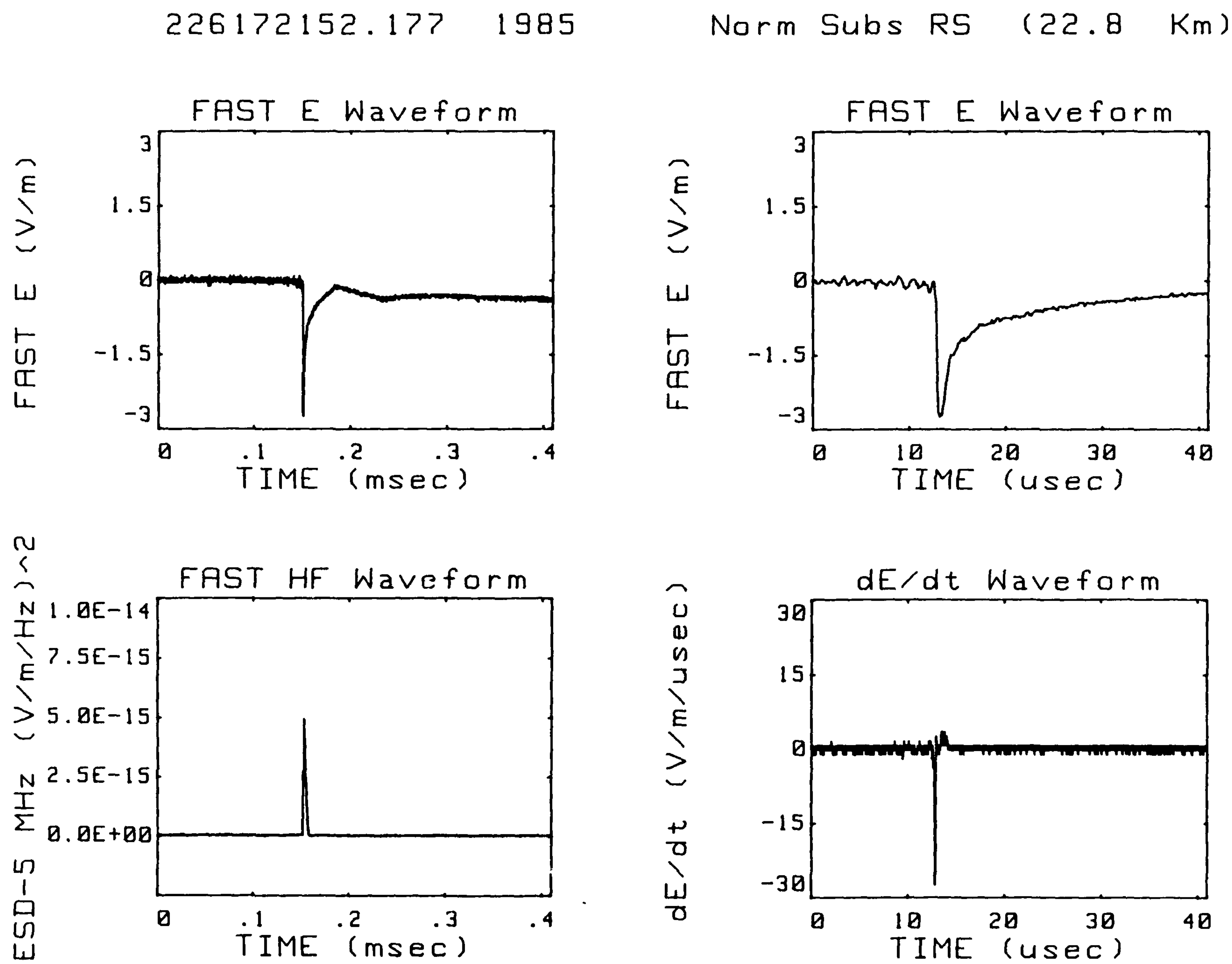


226172151.879 1985 1st RS (22.8 Km)

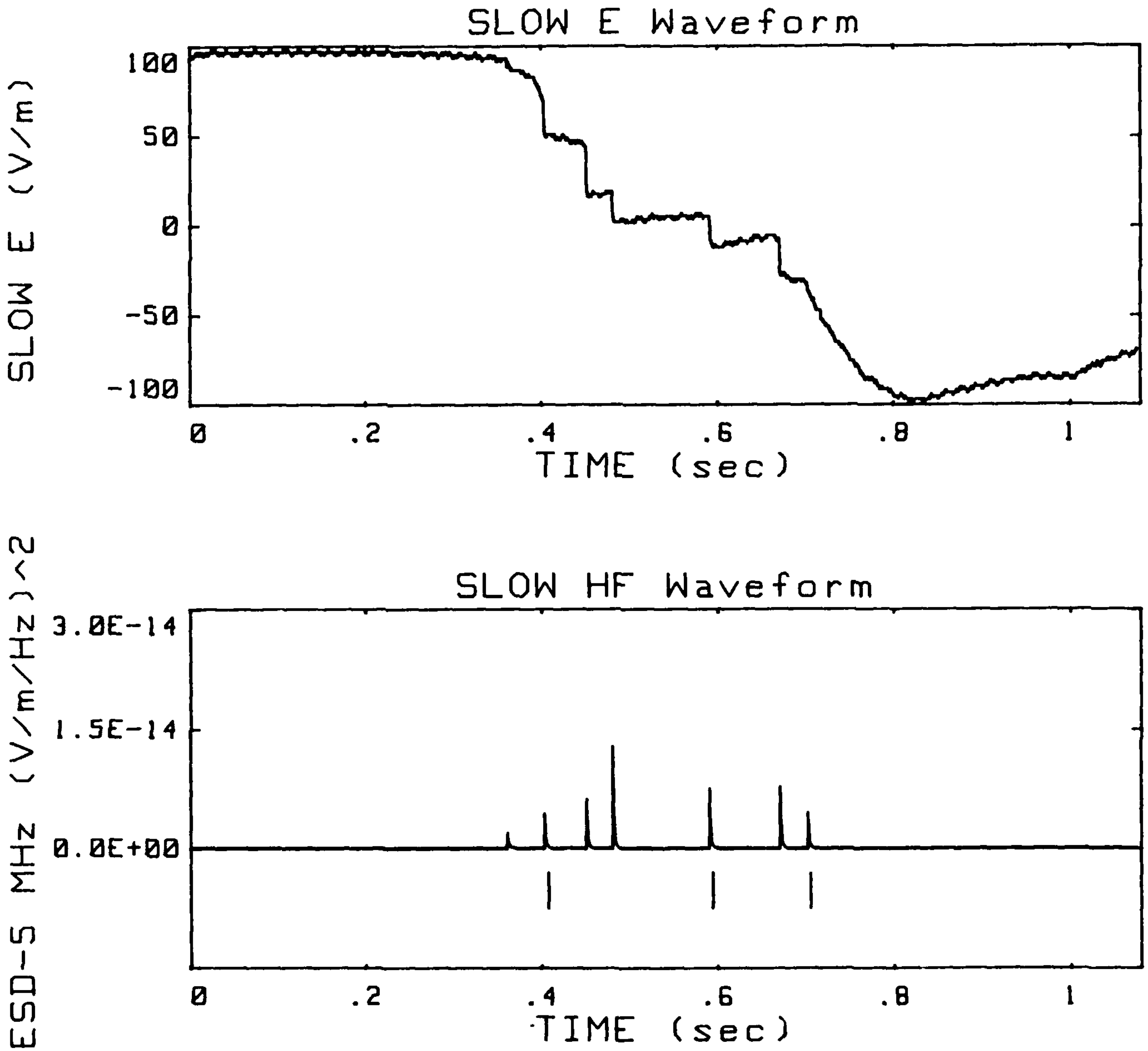


226172152.066 1985 DS Subs RS (22.8 Km)

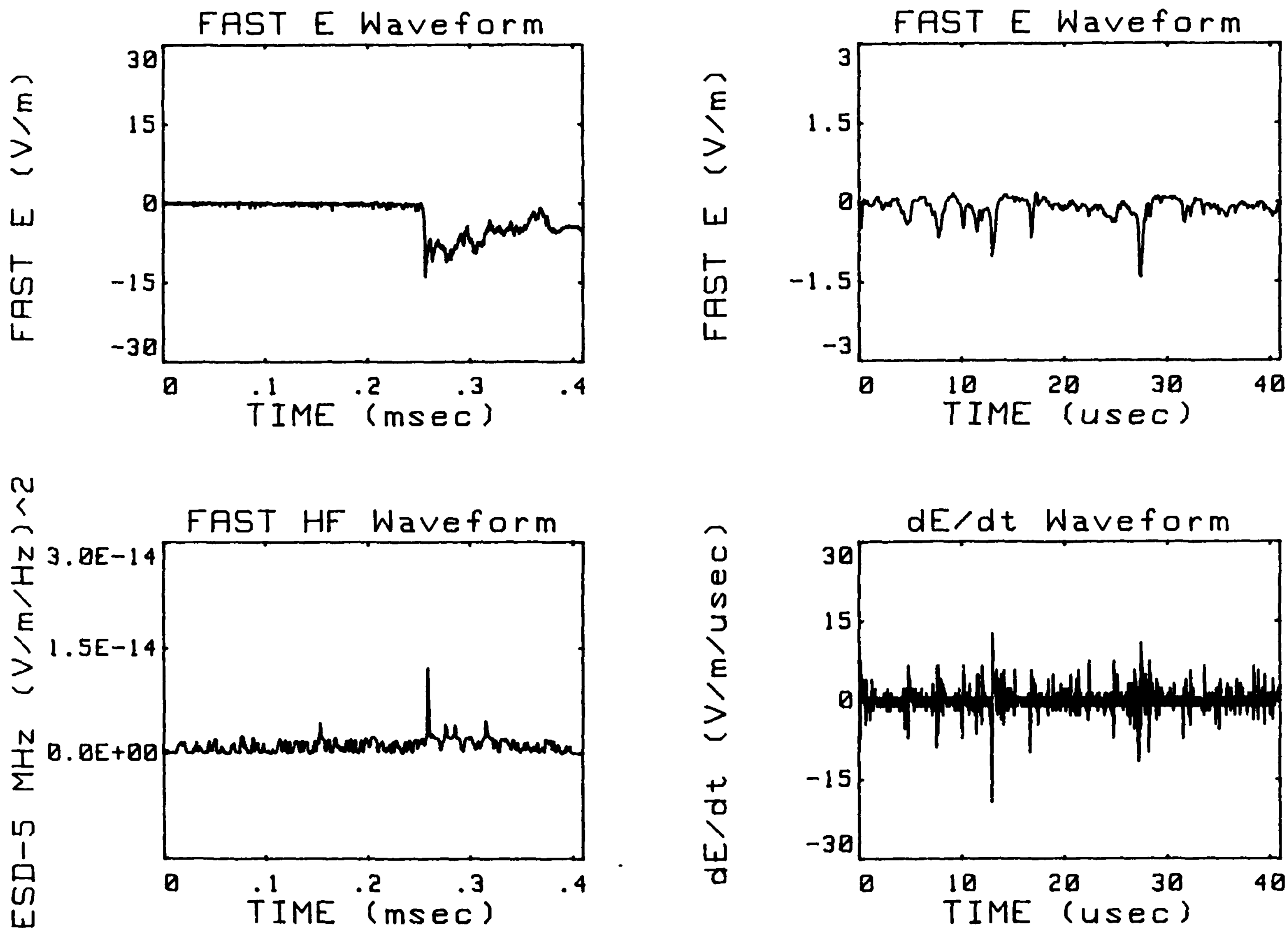



226172152.177 1985
Norm Subs RS (22.8 Km)
FAST E Waveform
FAST E (V/m)
3
1.5
0
-1.5
-3
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
3
1.5
0
-1.5
-3
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
1.0E-14
7.5E-15
5.0E-15
2.5E-15
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
30
15
0
-15
-30
0
10
20
30
40
TIME (usec)

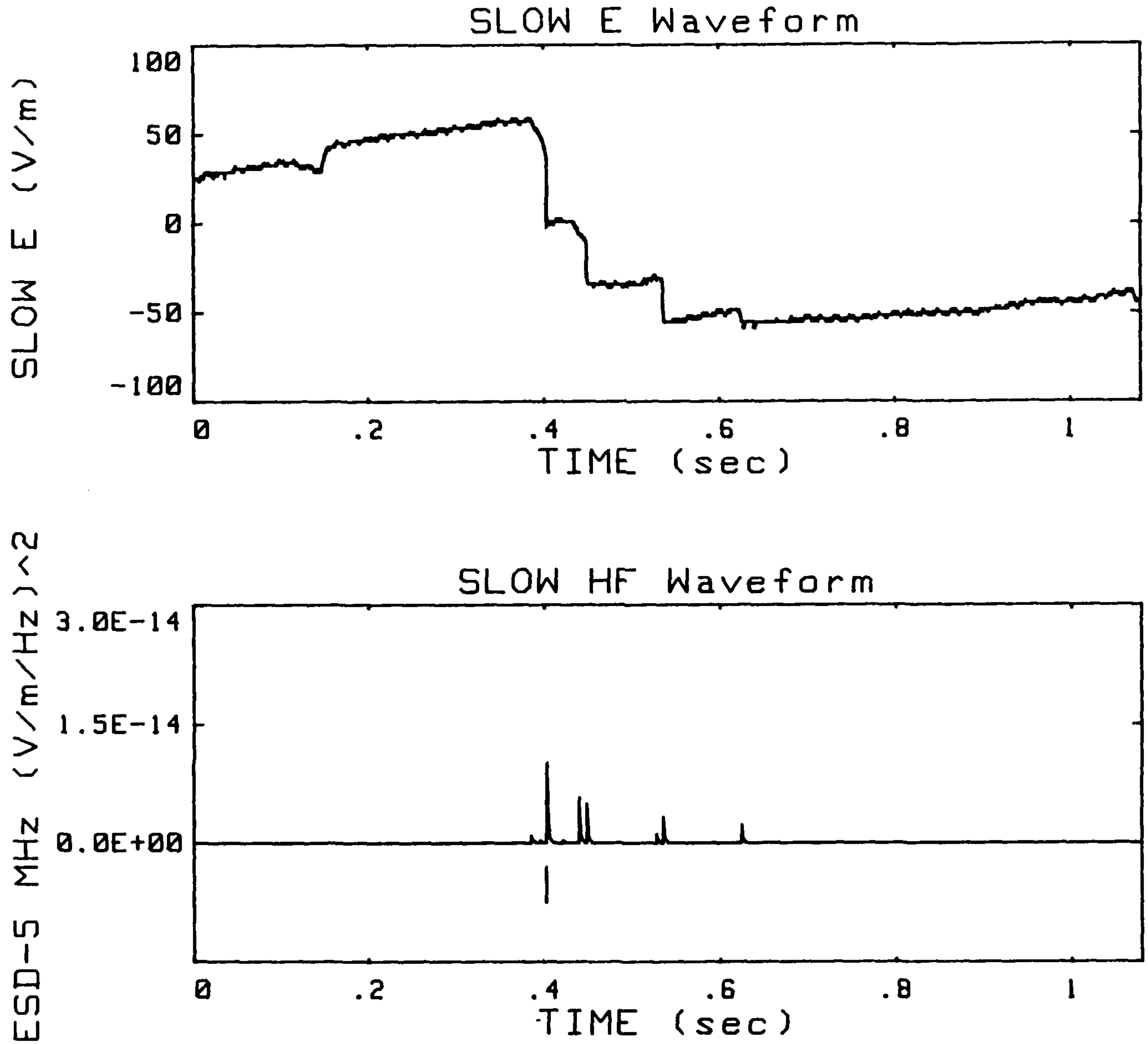
17:21:51.484 14 Aug 1985 (22.8 Km)



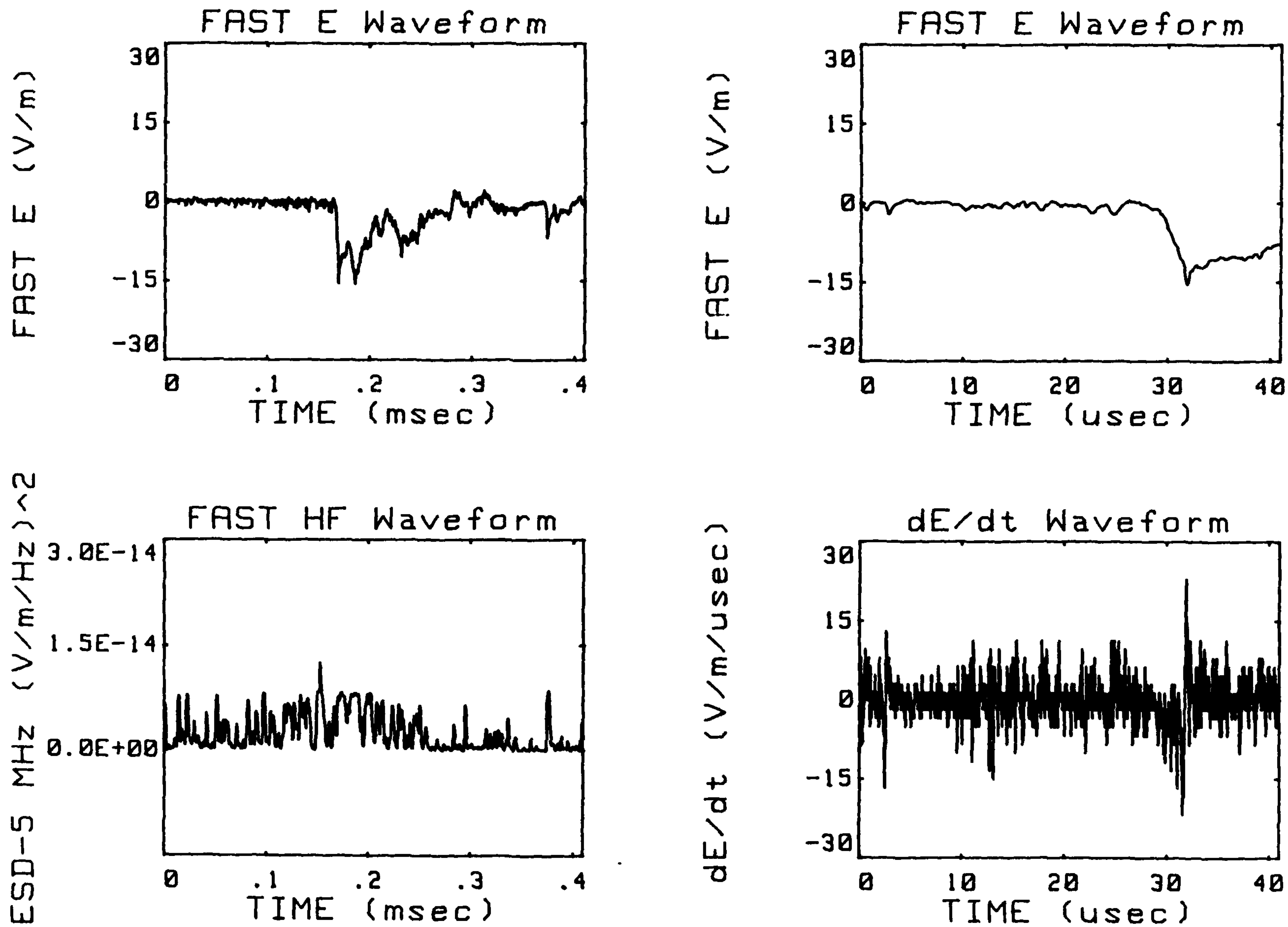
226172240.742 1985 Stepped Leader (21.1 Km)



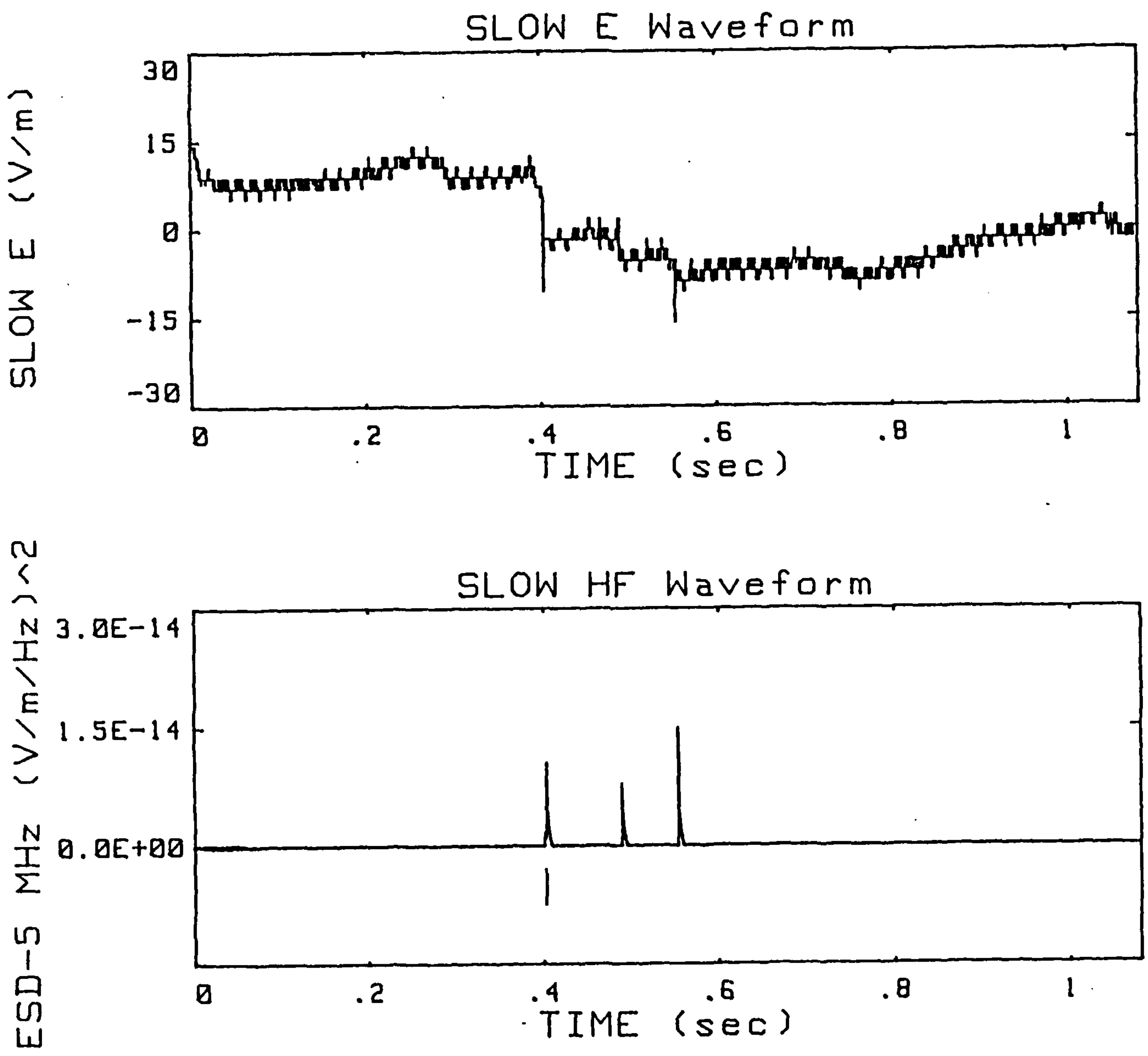
17:22:40.352 14 Aug 1985 (21.1 Km)



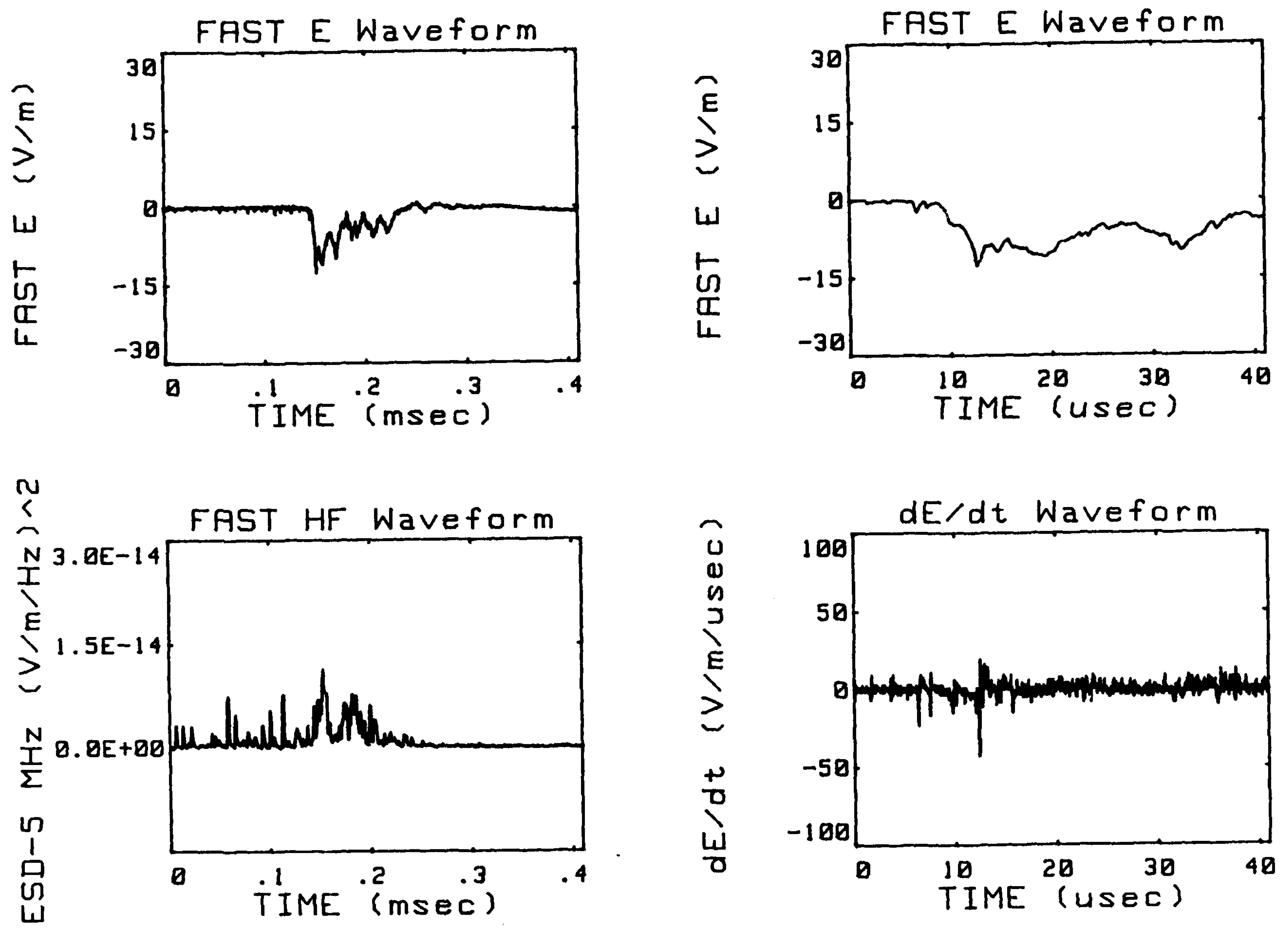
226172536.177 1985 1st RS (40.1 Km)



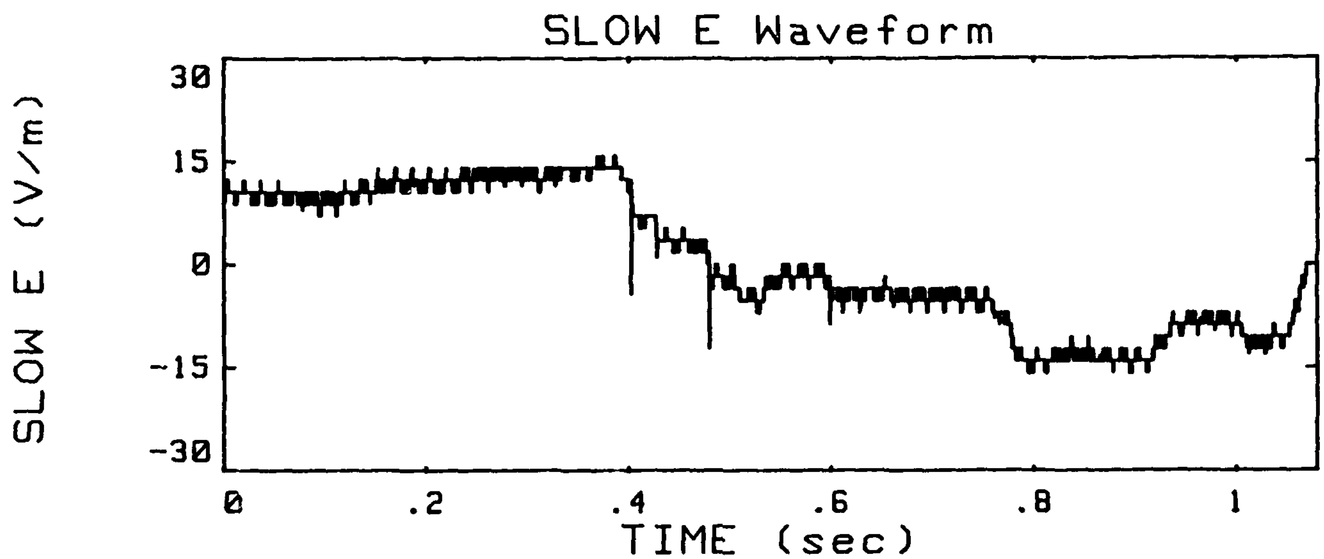
17:25:35.787 14 Aug 1985 (40.1 Km)

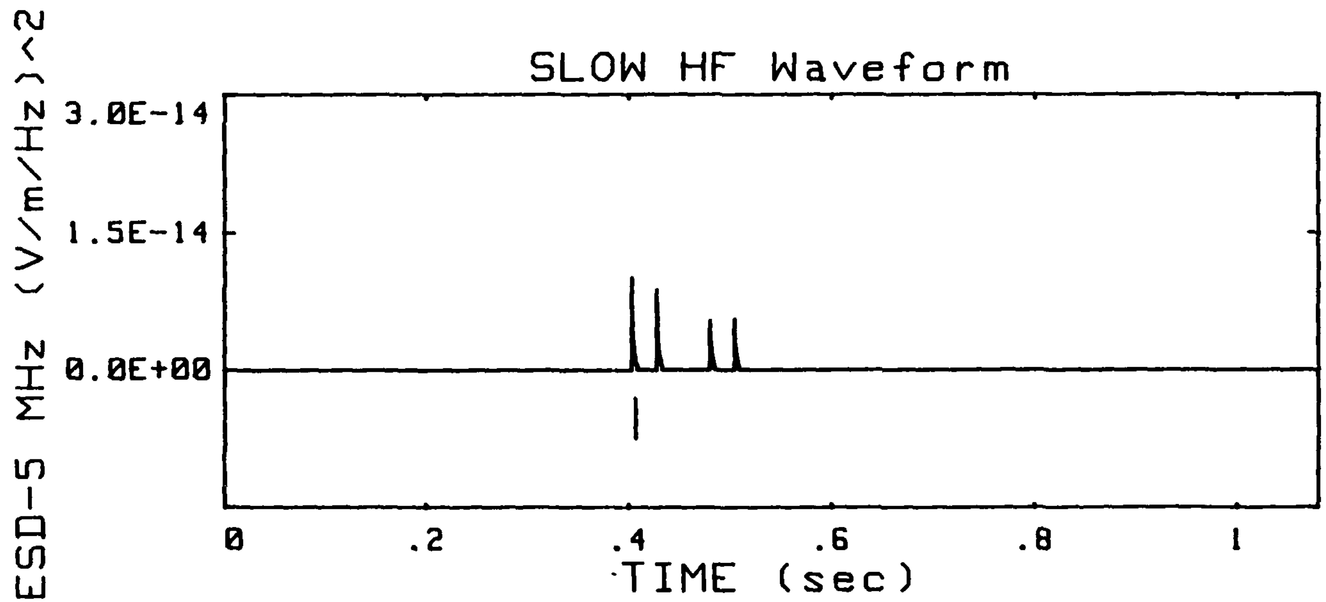


226172603.912 1985 1st RS (39.9 Km)

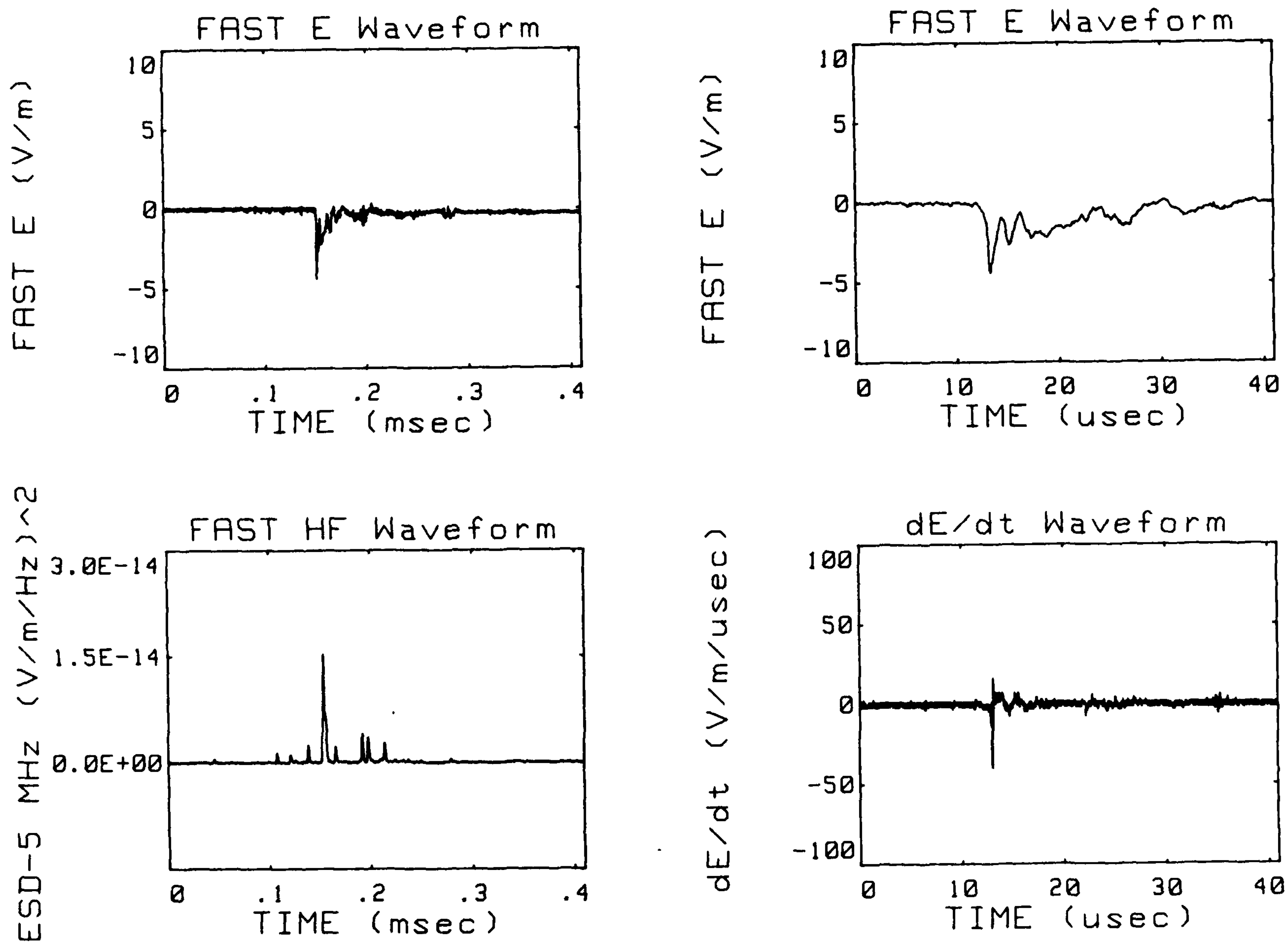


17:26:03.518 14 Aug 1985 (39.9 Km)

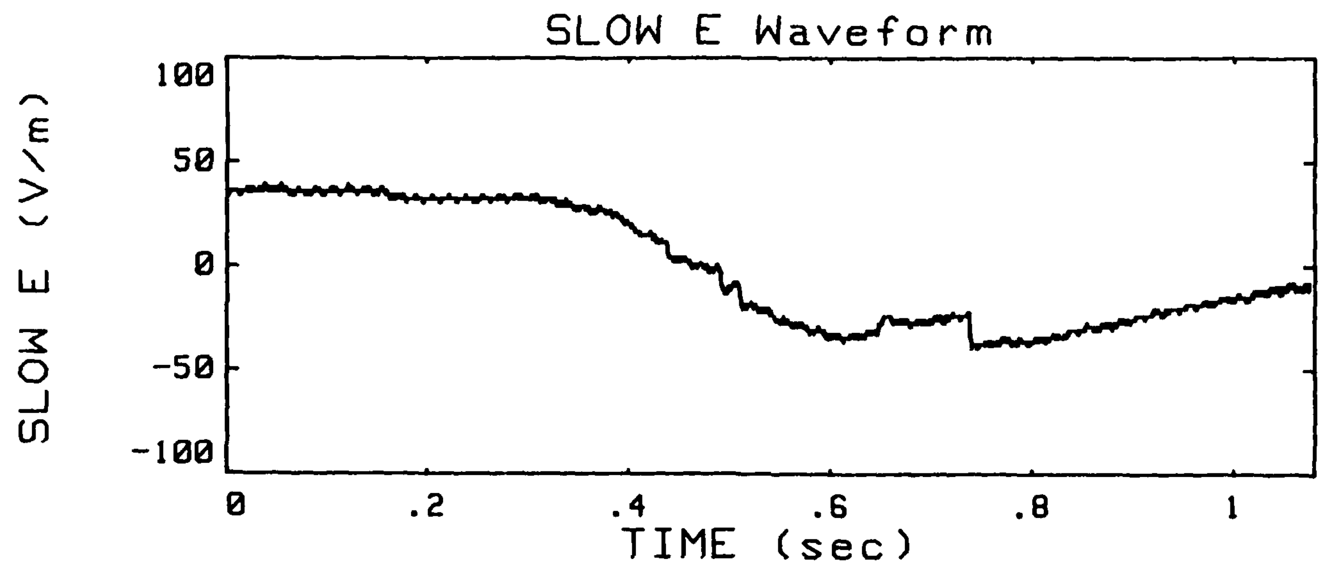


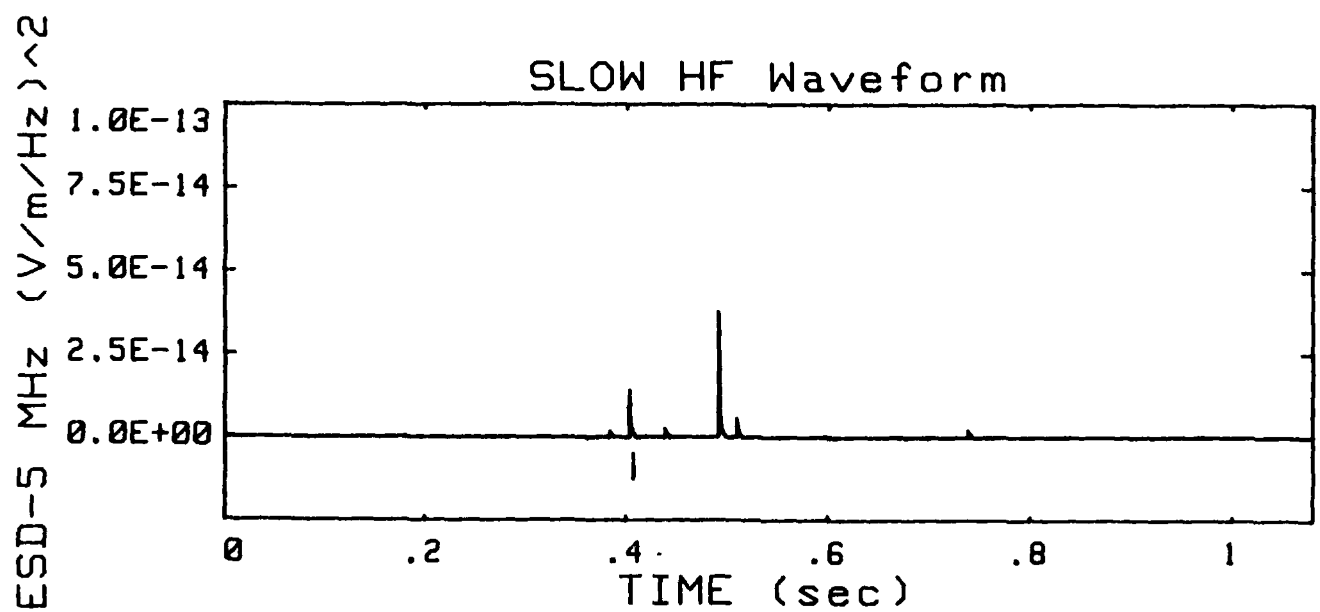


226172618.427 1985 1st RS (35.7 Km)

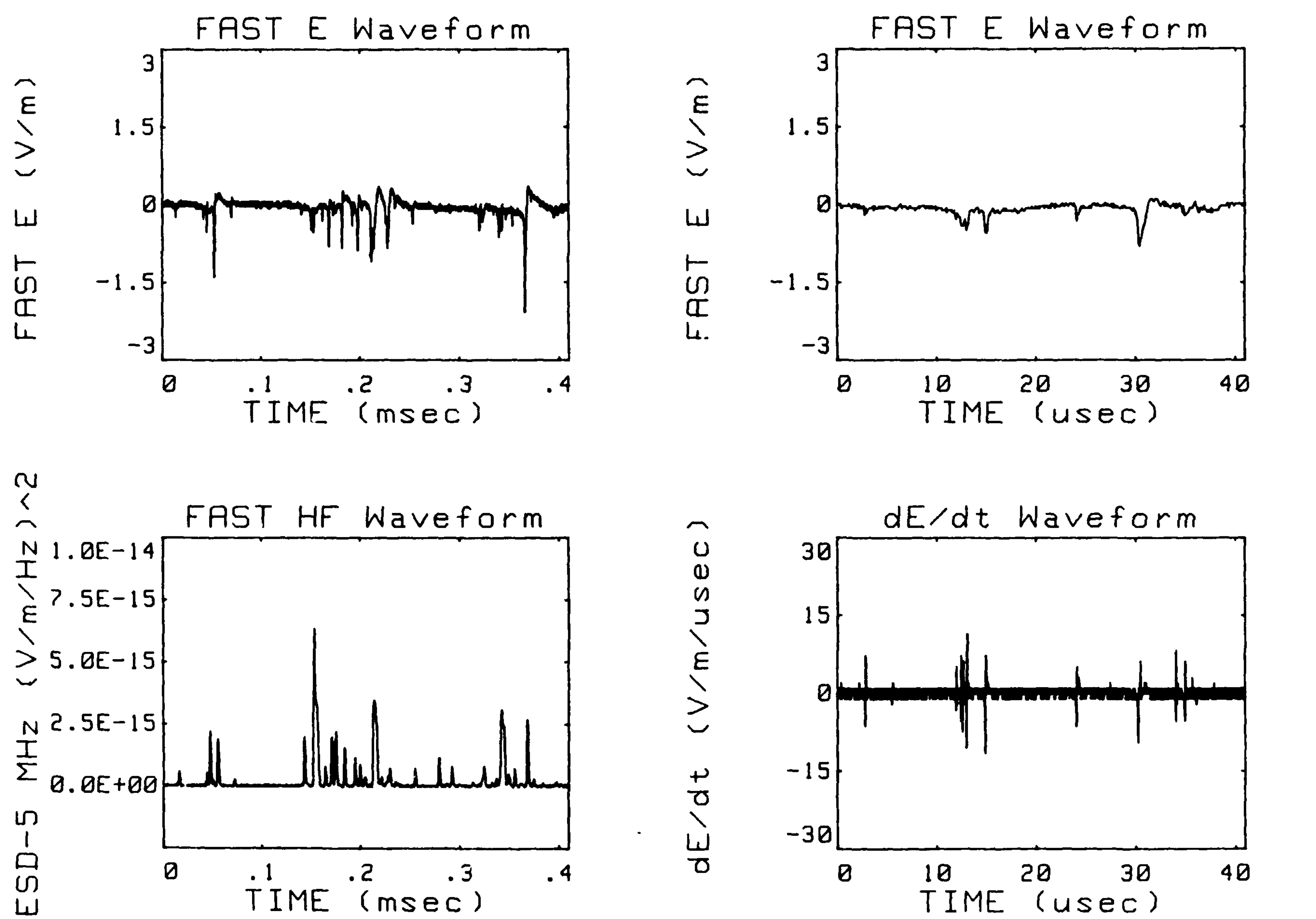


17:26:18.033 14 Aug 1985 (35.7 Km)

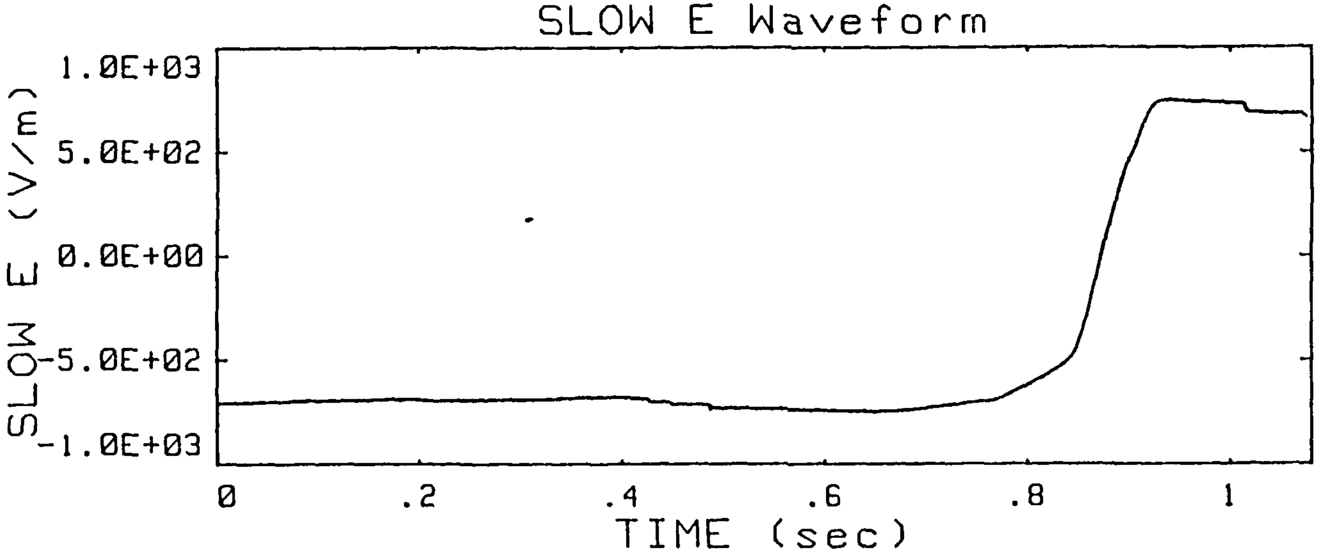


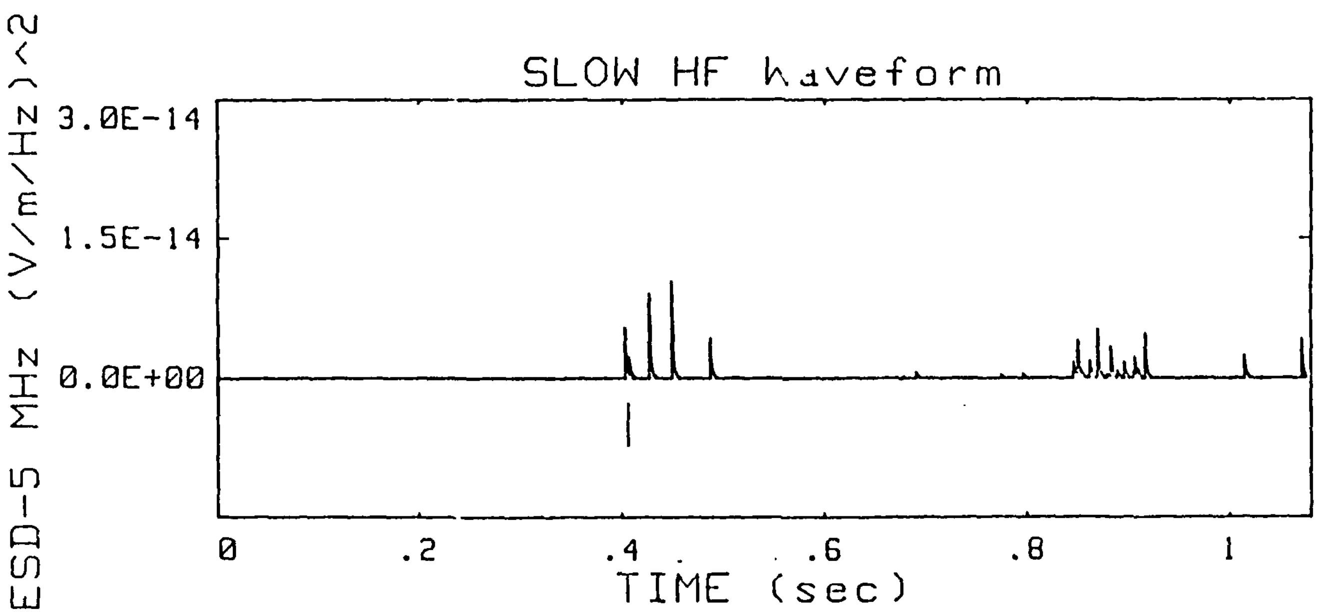


226172706.747 1985 Char Cloud Pulse (25.2 Km)

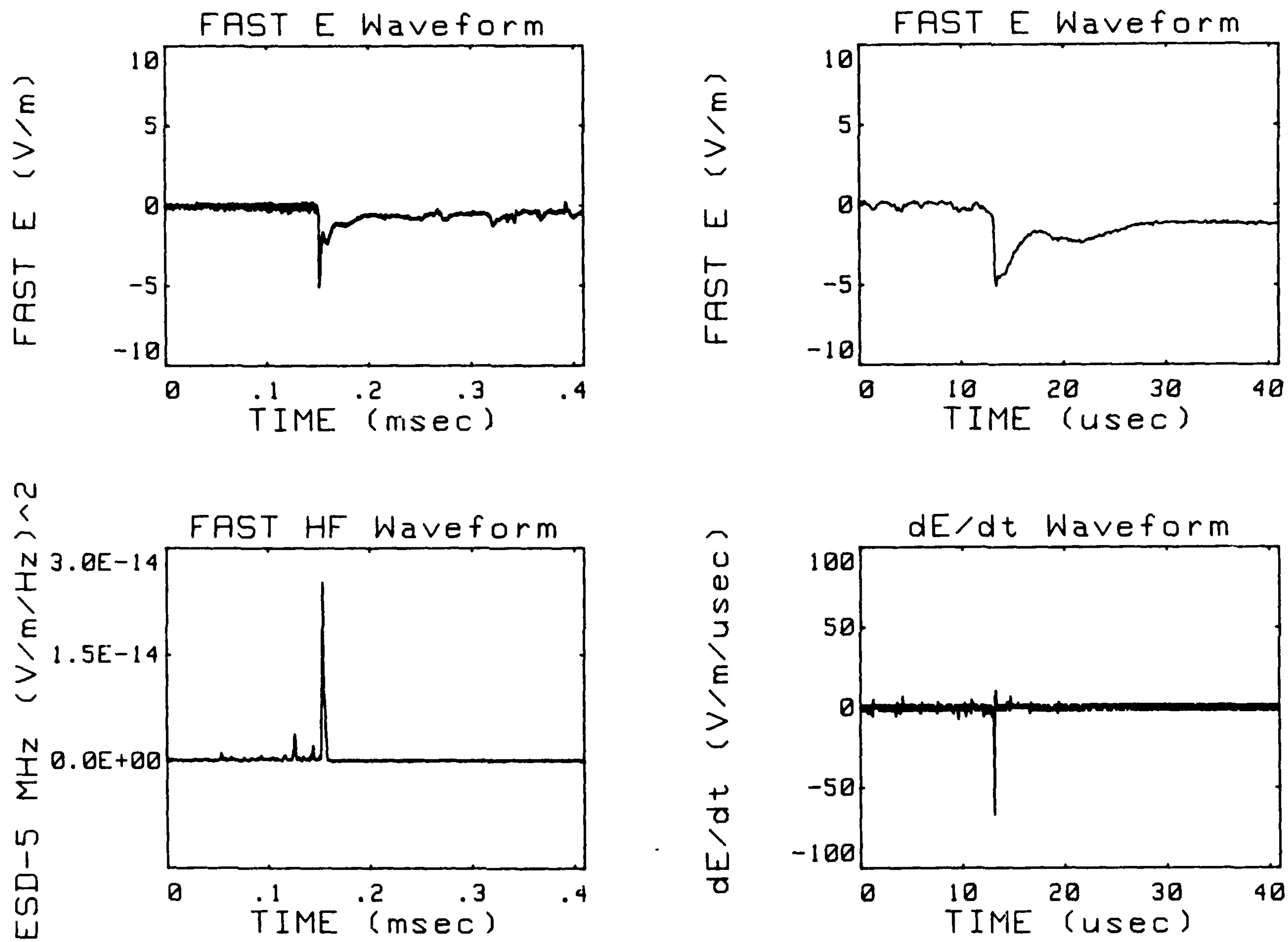


17:27:06.356 14 Aug 1985 (25.2 Km)

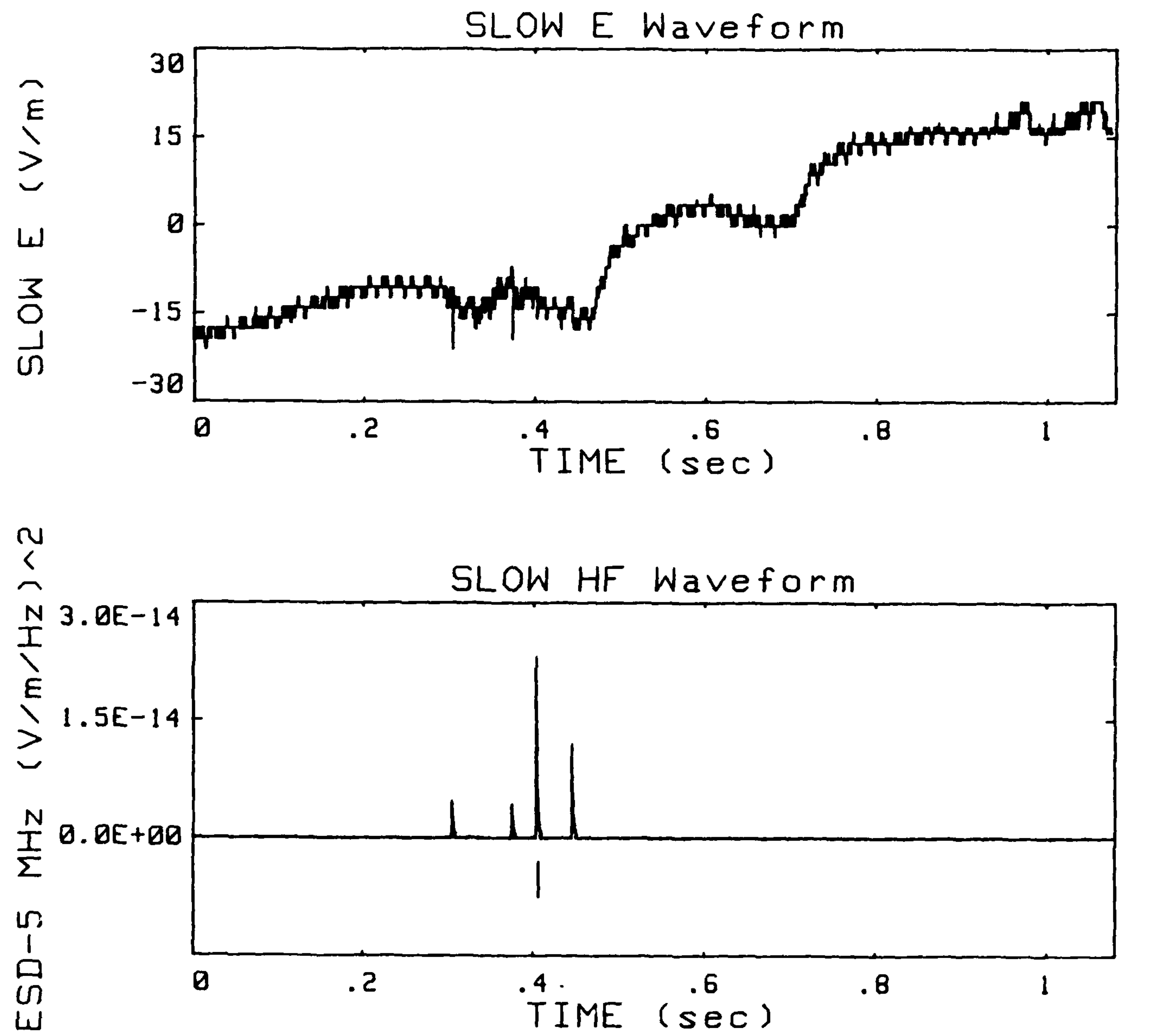




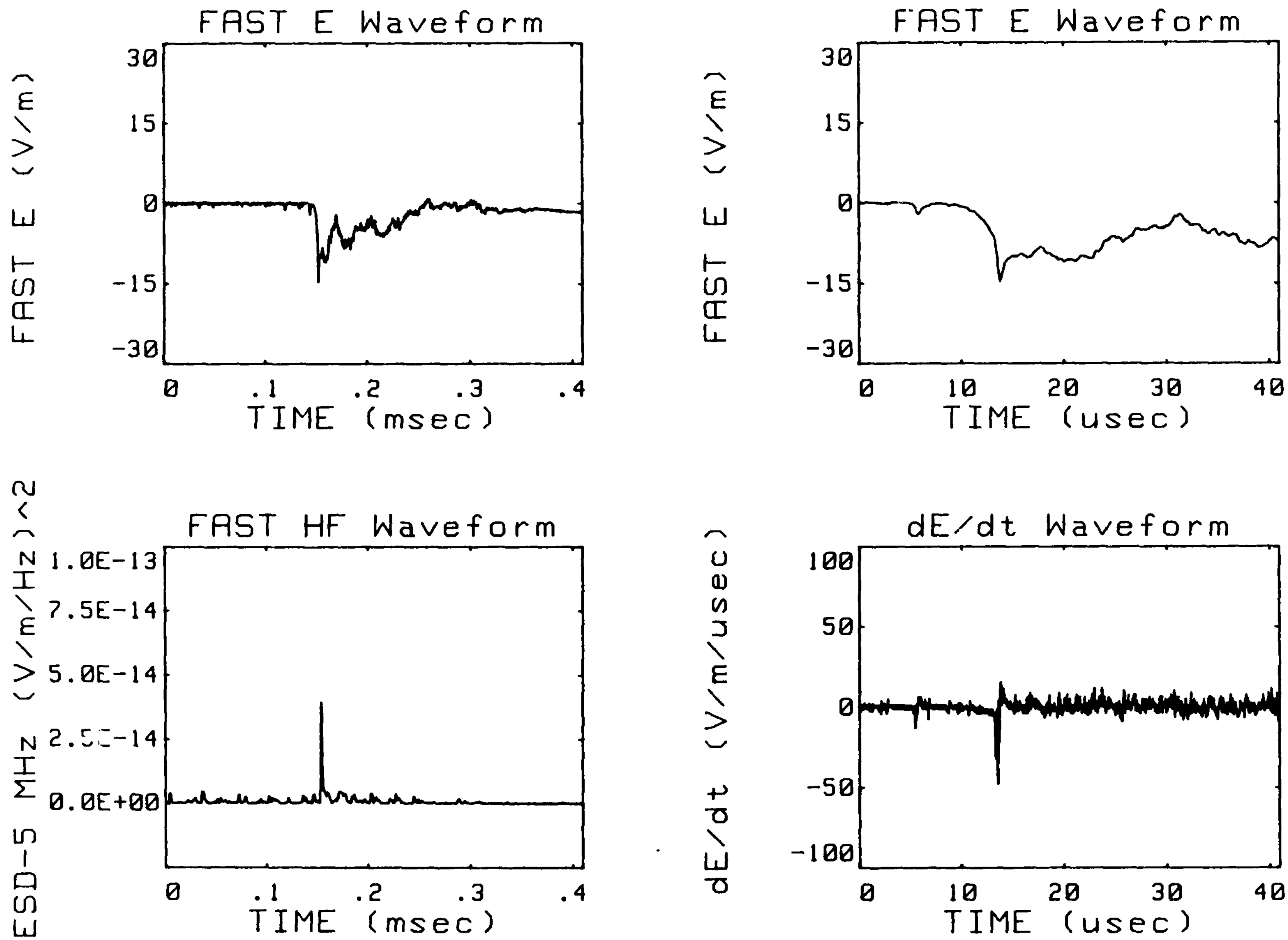
226172728.235 1985 Chaotic Subs RS (42.4 Km)



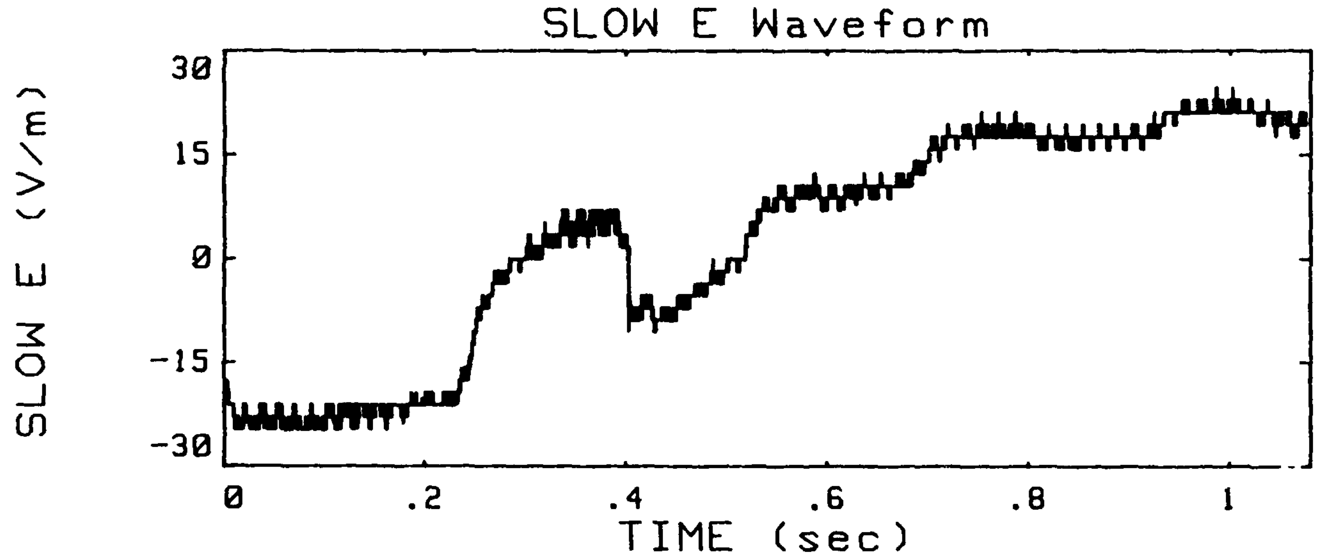
17:27:27.842 14 Aug 1985 (42.4 Km)

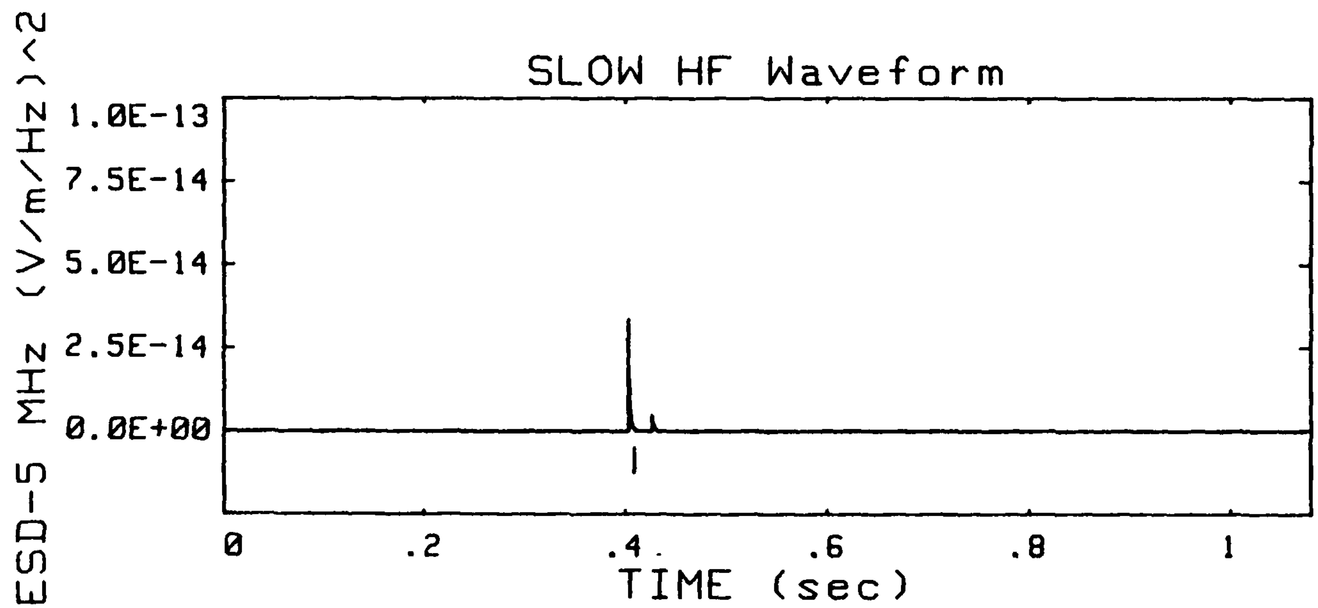


226172743.555 1985 1st RS (31.2 Km)

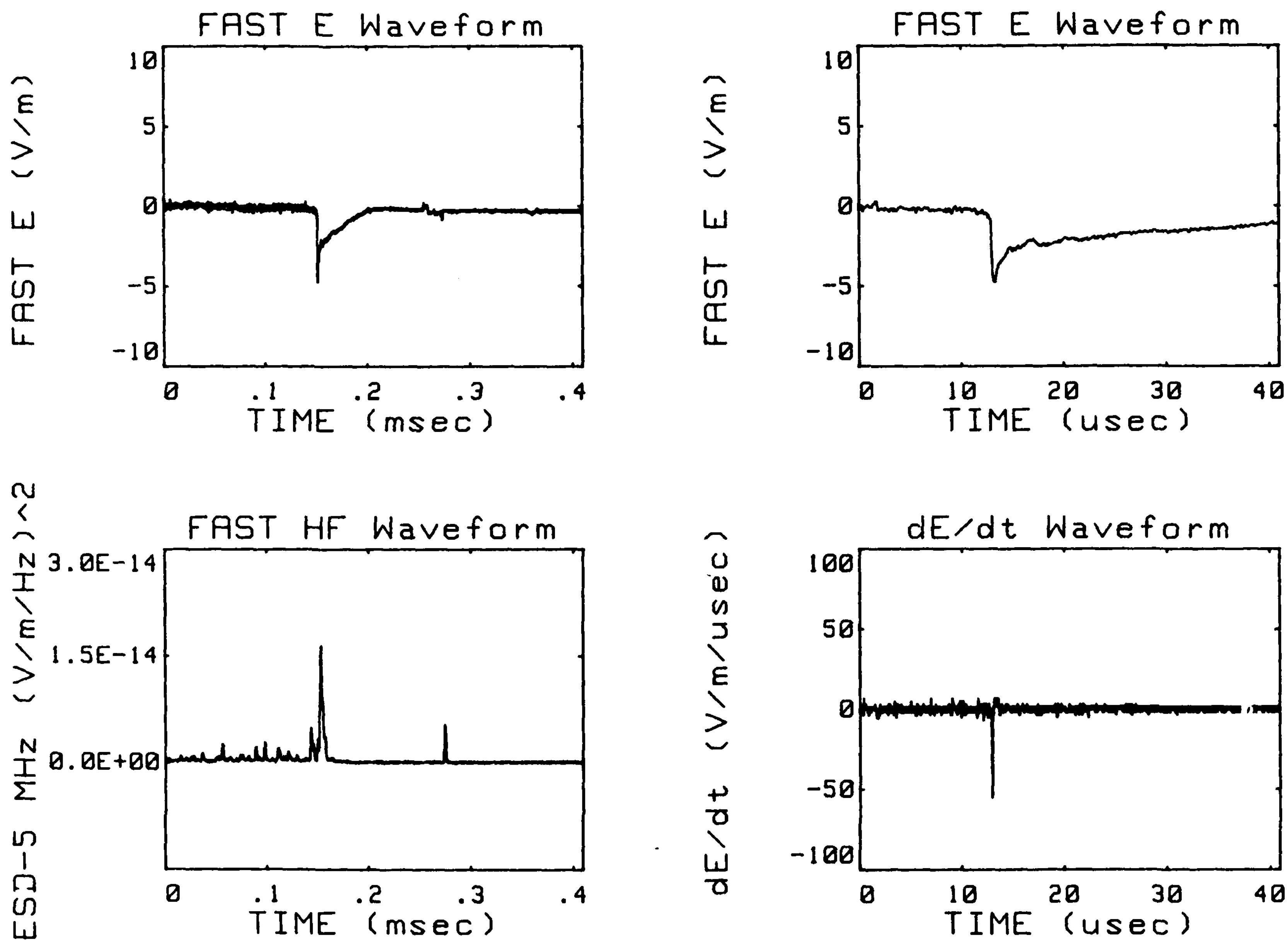


17:27:43.159 14 Aug 1985 (31.2 Km)

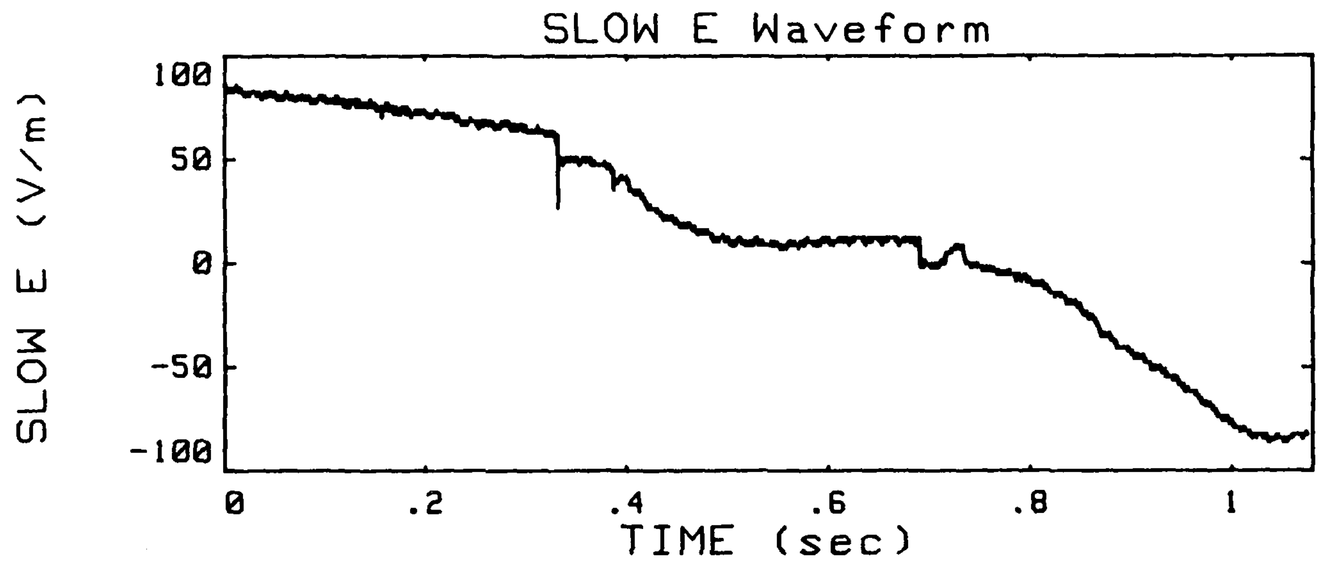


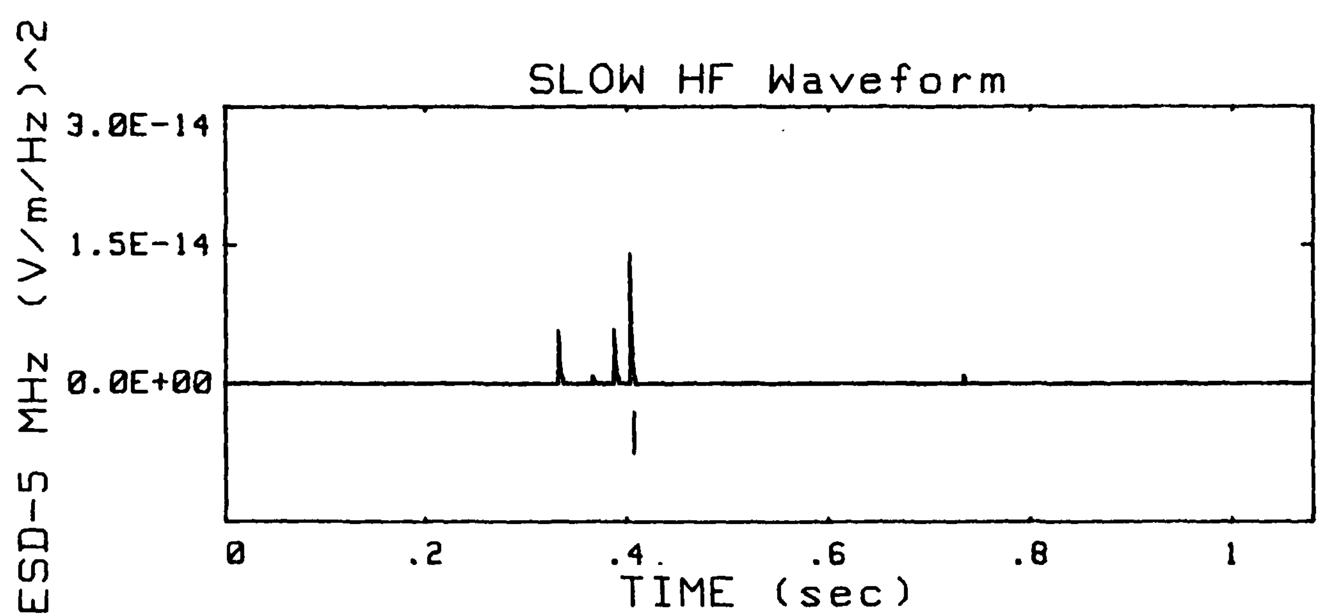


226172831.101 1985 Norm Subs RS (41.6 Km)

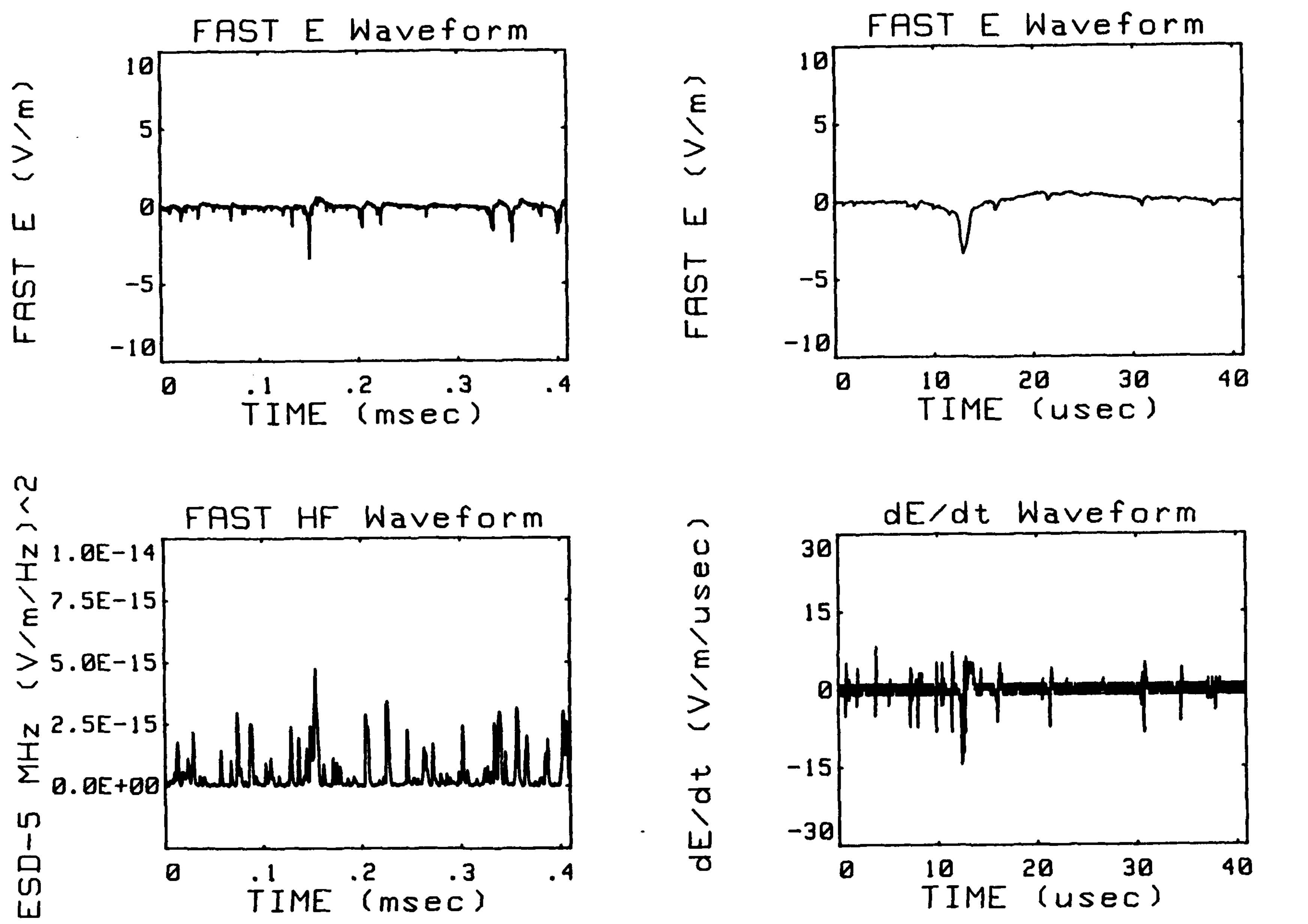


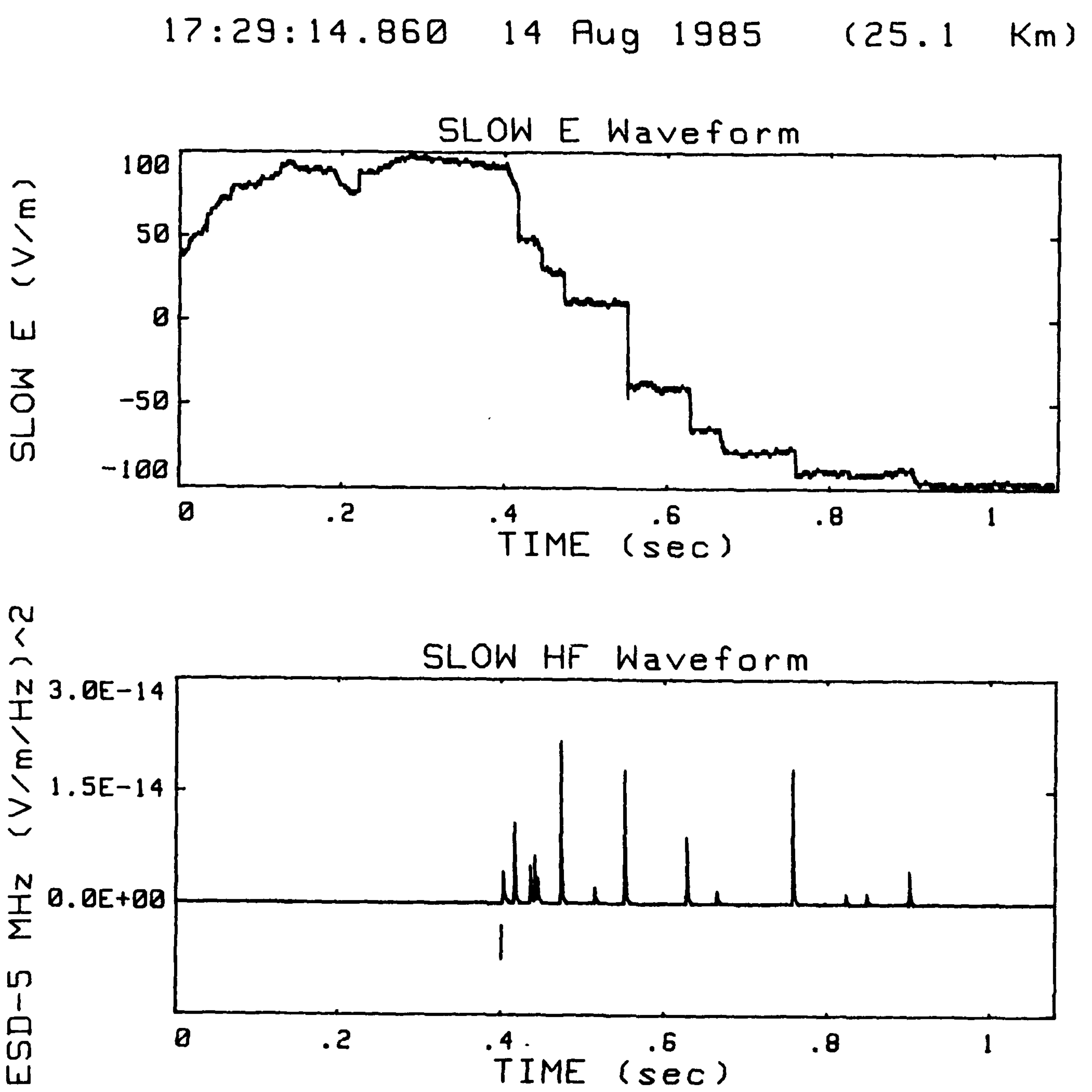
17:28:30.707 14 Aug 1985 (41.6 Km)



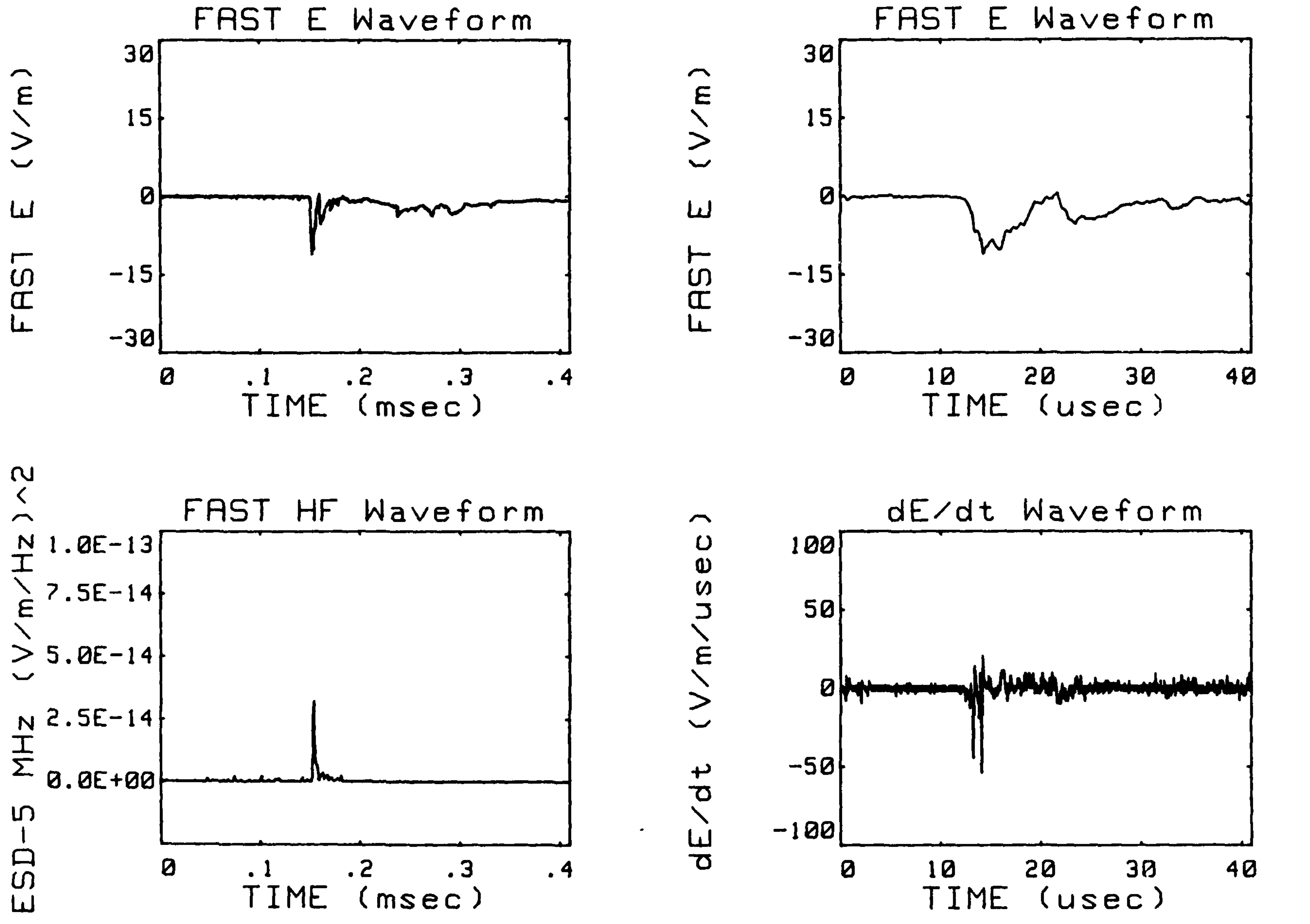


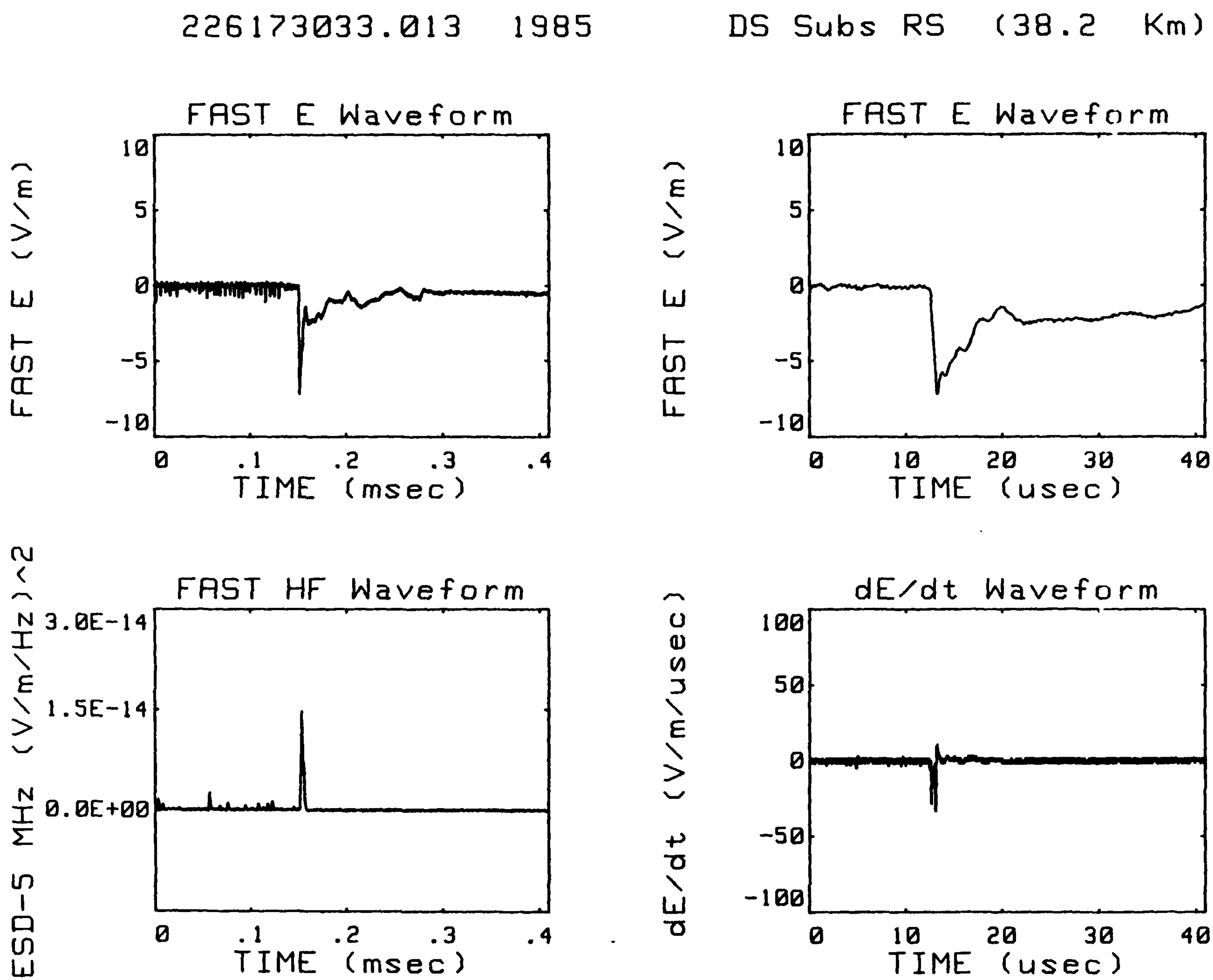
226172915.248 1985 Char Cloud Pulse (25.1 Km)

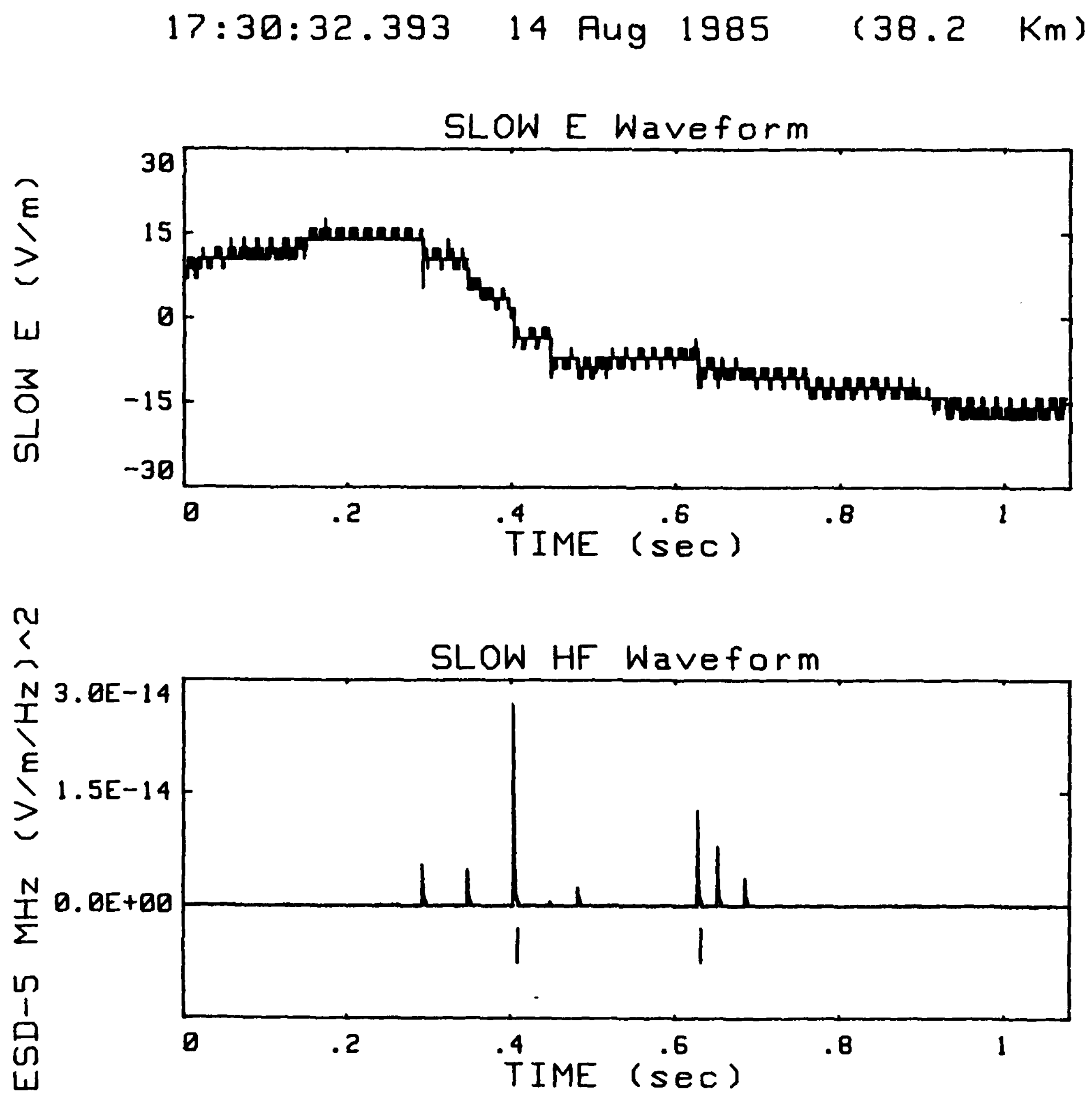



17:29:14.860 14 Aug 1985 (25.1 Km)
SLOW E Waveform
SLOW E (V/m)
100
50
0
-50
-100
0
.2
.4
.6
.8
1
TIME (sec)
SLOW HF Waveform
ESD-5 MHz (V/m/Hz)^2
3.0E-14
1.5E-14
0.0E+00
0
.2
.4
.6
.8
1
TIME (sec)

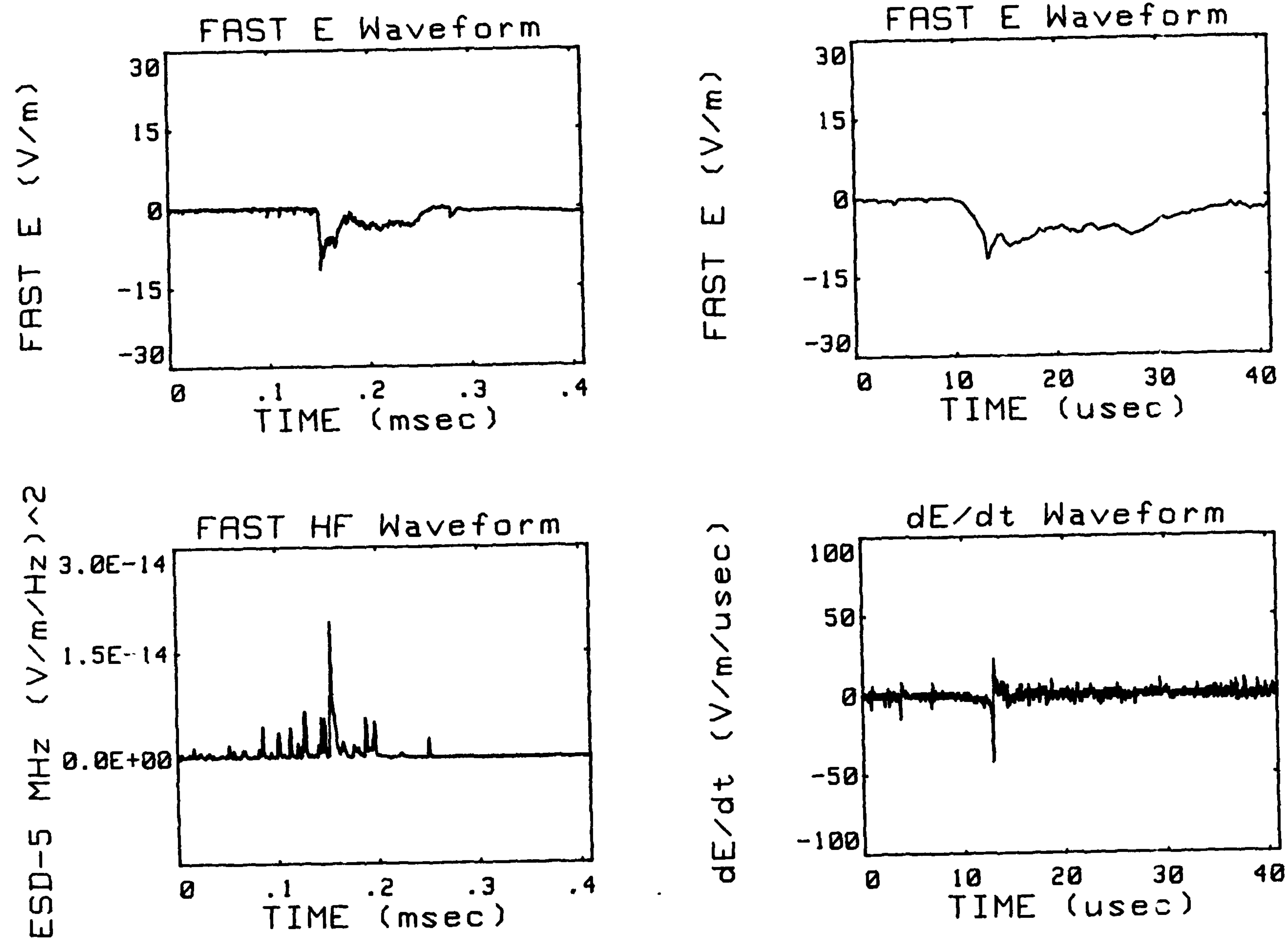
226173032.789 1985 1st RS (38.2 Km)



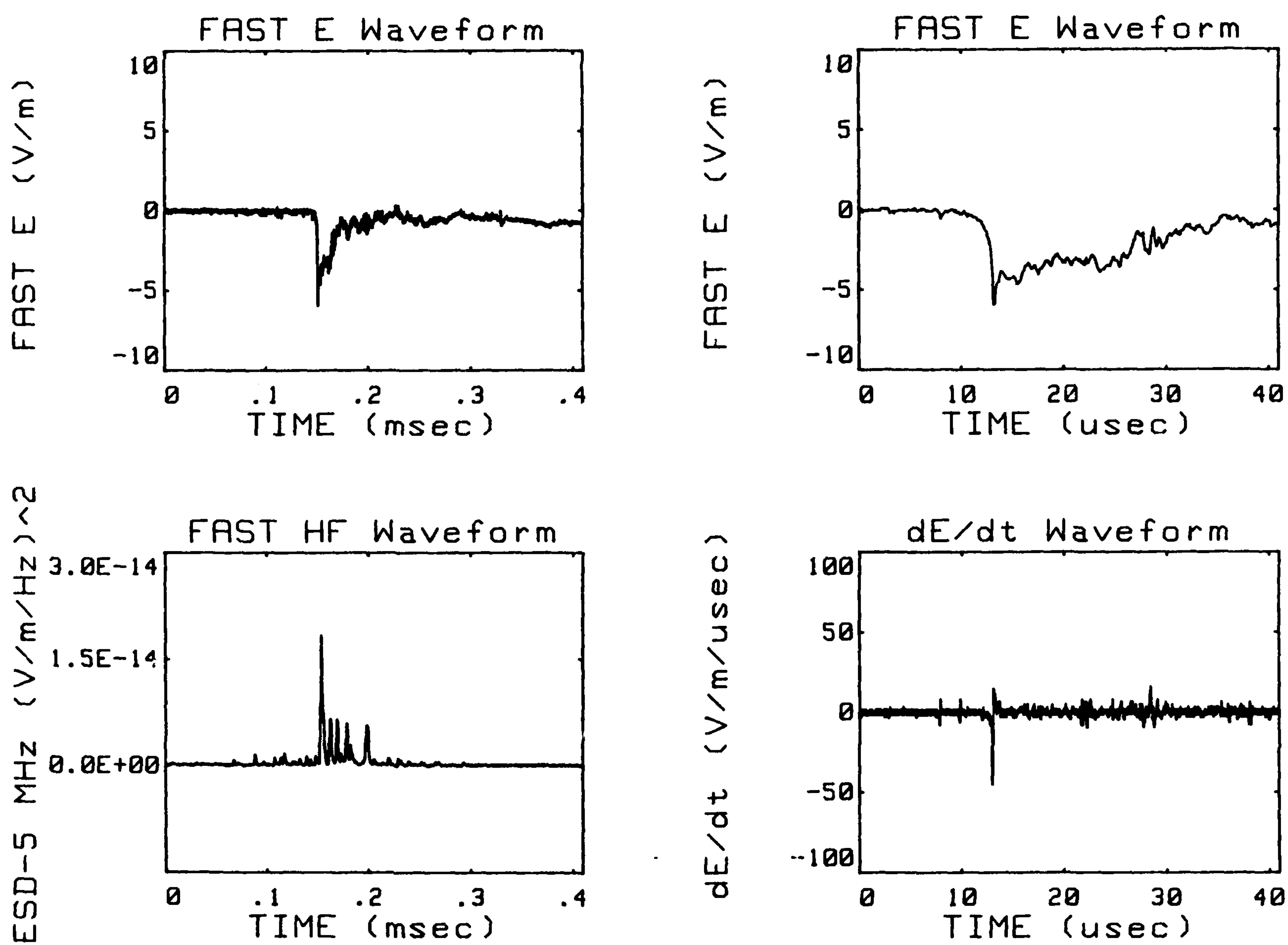

226173033.013 1985
DS Subs RS (38.2 Km)
FAST E Waveform
FAST E (V/m)
TIME (msec)
FAST E Waveform
FAST E (V/m)
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
3.0E-14
1.5E-14
0.0E+00
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
TIME (usec)


17:30:32.393 14 Aug 1985 (38.2 Km)
SLOW E Waveform
SLOW E (V/m)
30
15
0
-15
-30
0
.2
.4
.6
.8
1
TIME (sec)
SLOW HF Waveform
ESD-5 MHz (V/m/Hz)^2
3.0E-14
1.5E-14
0.0E+00
0
.2
.4
.6
.8
1
TIME (sec)

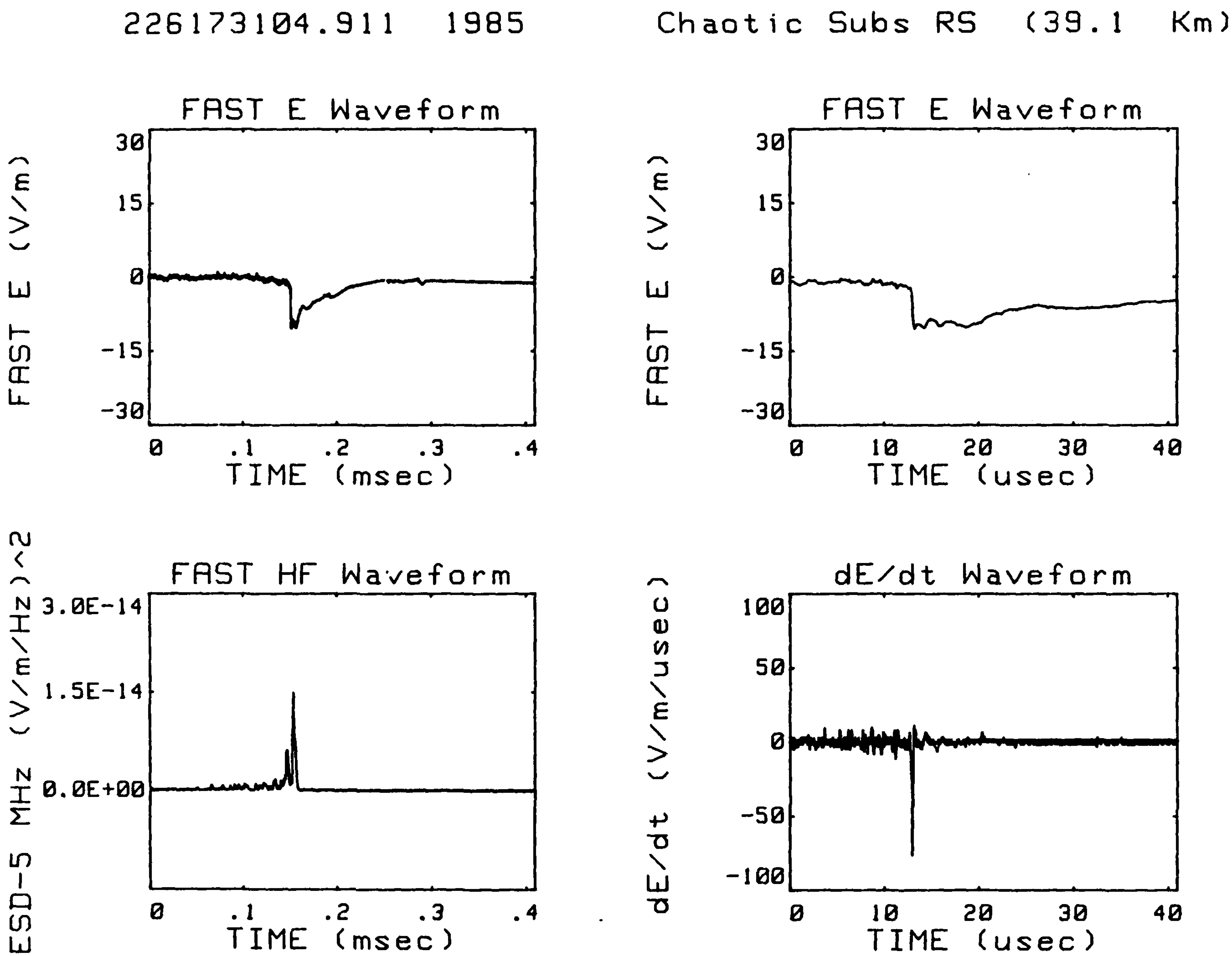
226173104.677 1985 1st RS (39.1 Km)



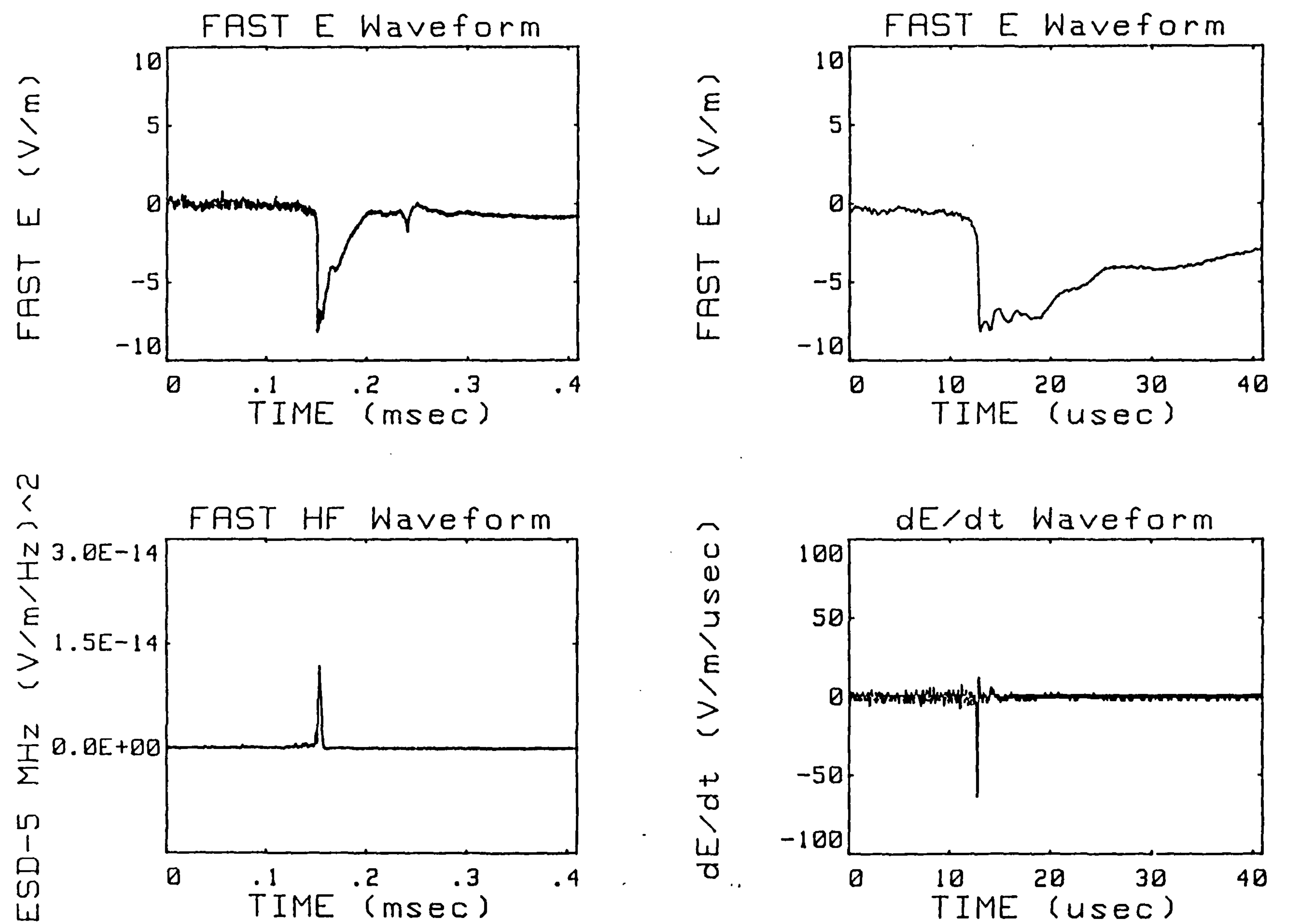
226173104.815   1985   1st RS   (39.1   Km)

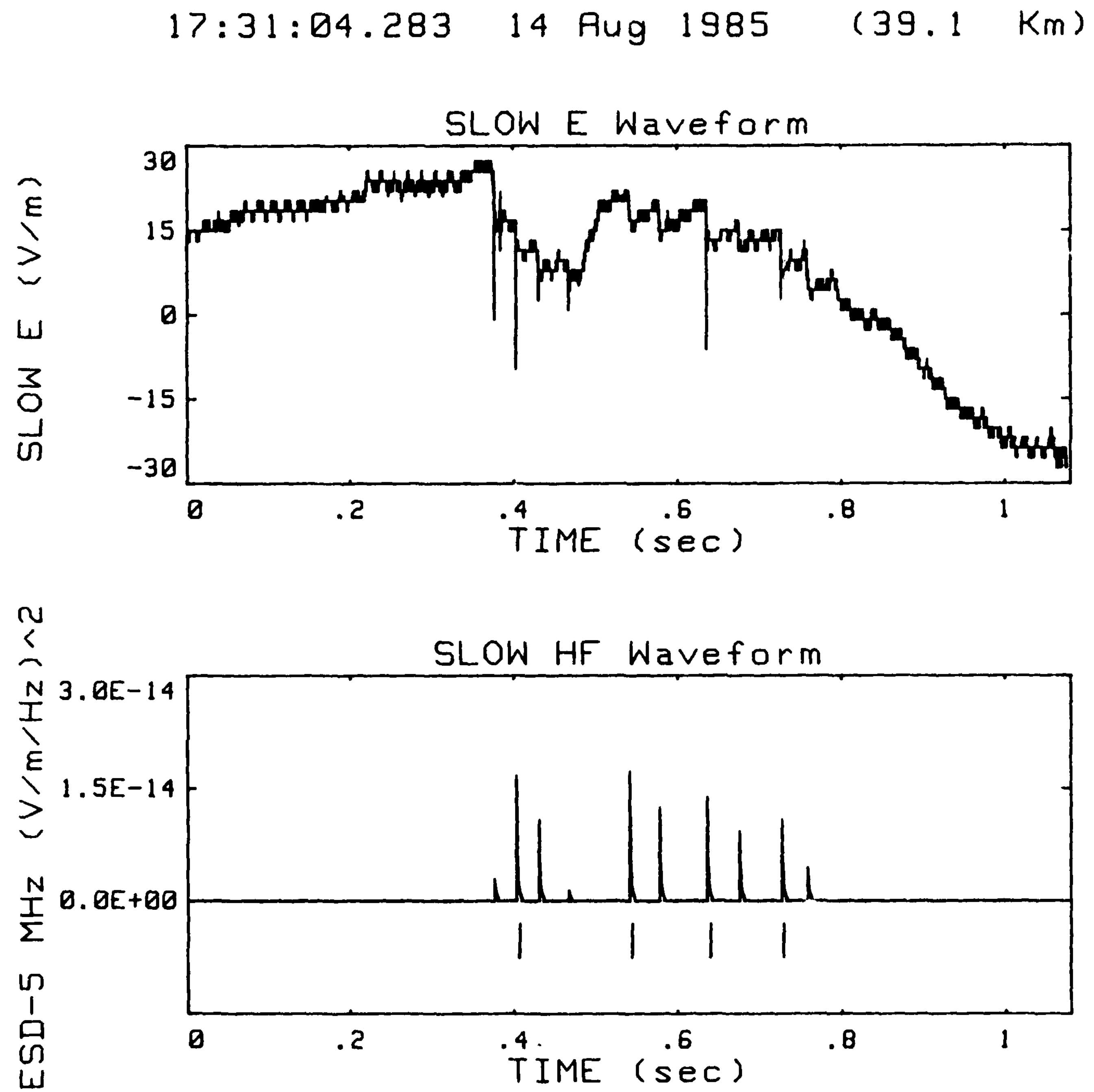


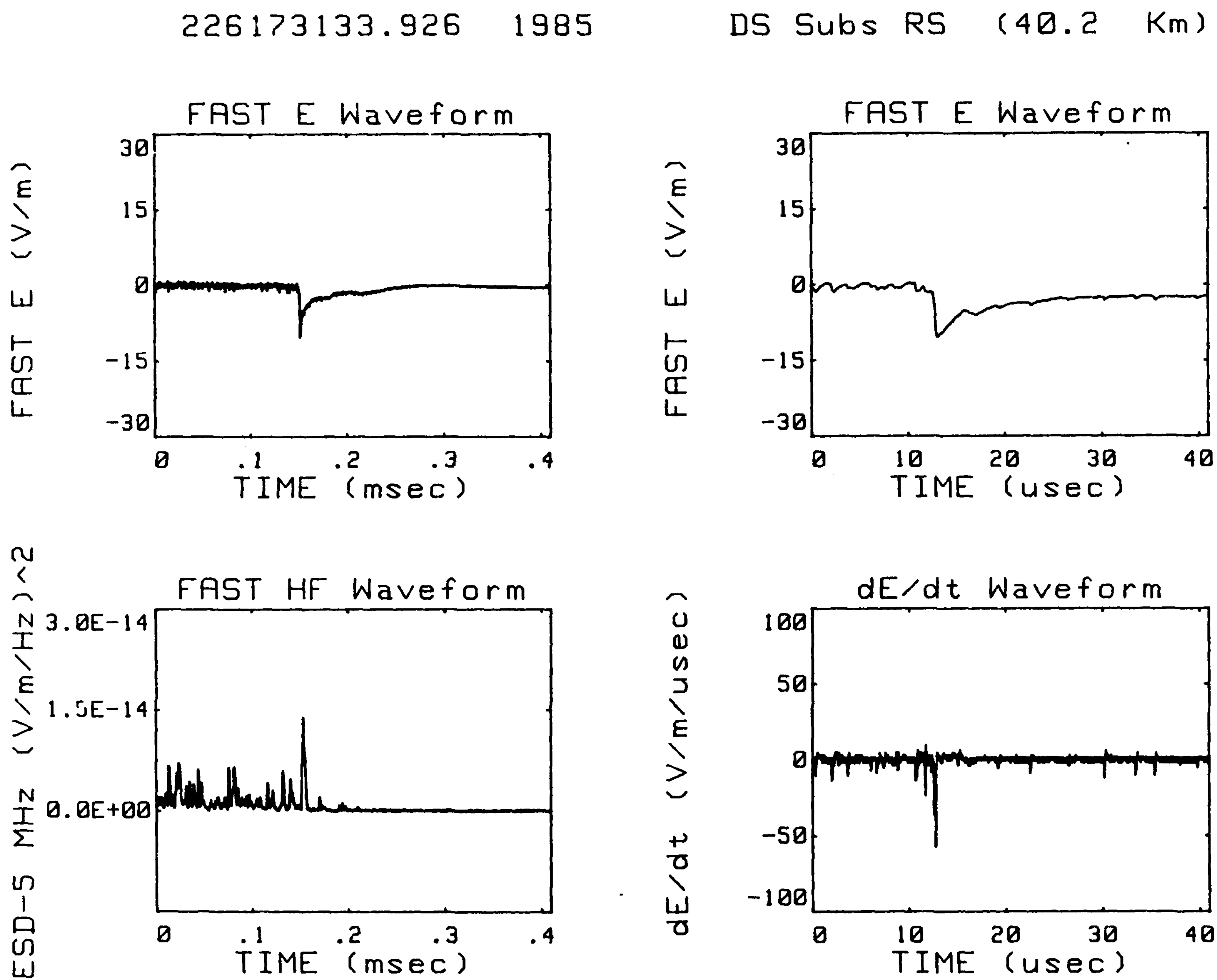
144


226173104.911 1985
Chaotic Subs RS (39.1 Km)
FAST E Waveform
FAST E (V/m)
30
15
0
-15
-30
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
30
15
0
-15
-30
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
3.0E-14
1.5E-14
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
100
50
0
-50
-100
0
10
20
30
40
TIME (usec)

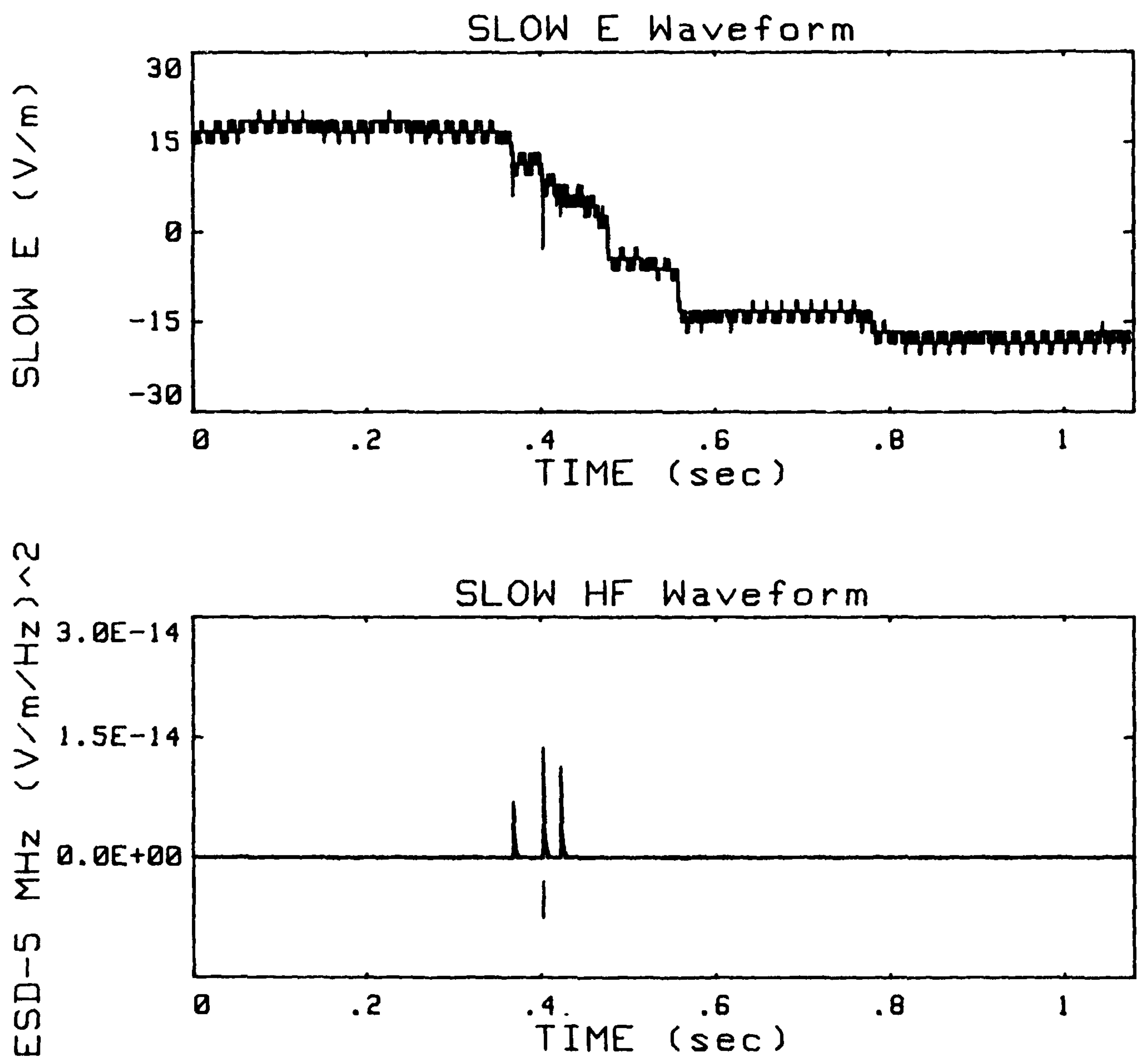
226173105.000 1985 Chaotic Subs RS (39.1 Km)



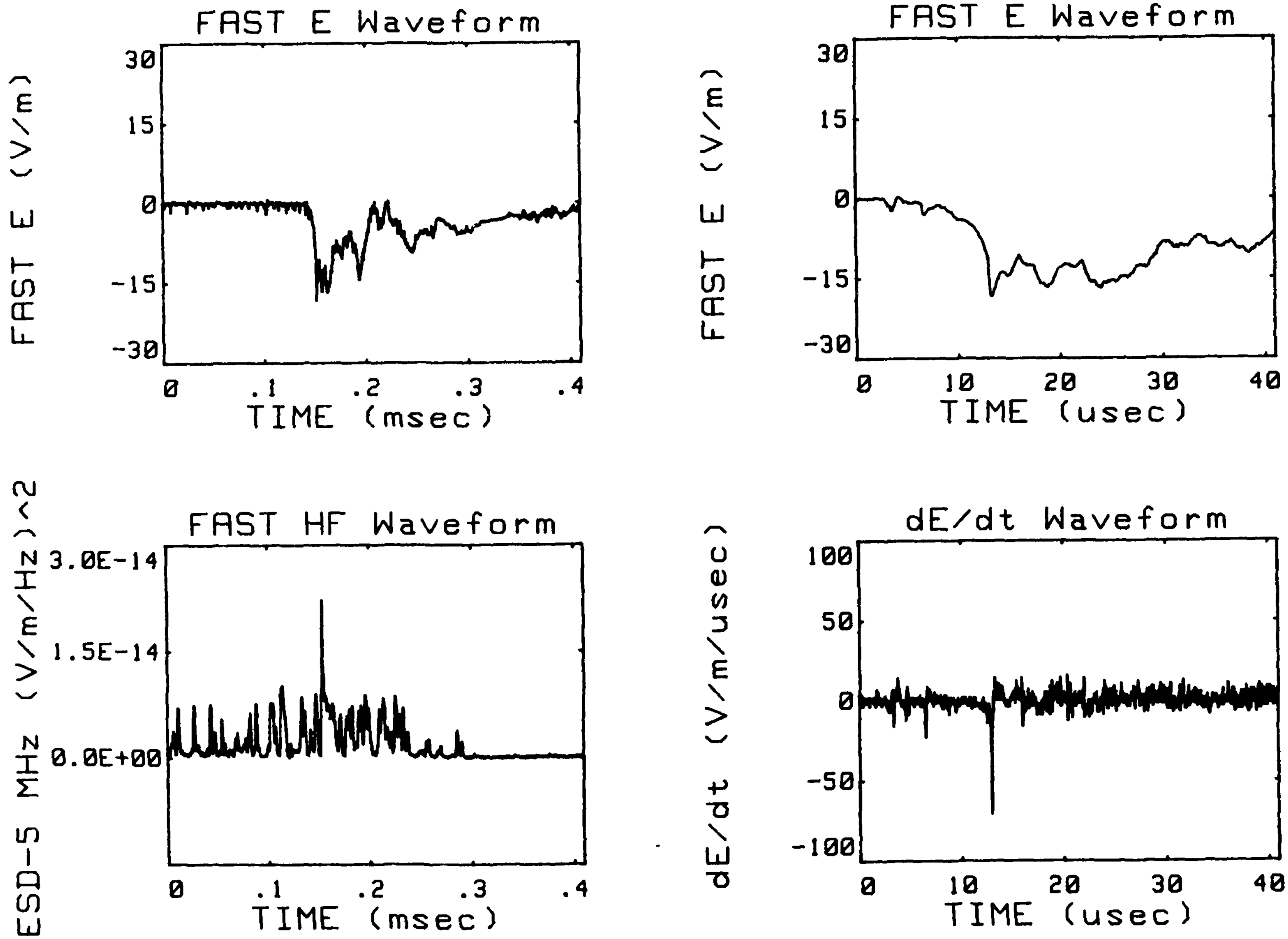

17:31:04.283 14 Aug 1985 (39.1 Km)
SLOW E Waveform
SLOW E (V/m)
30
15
0
-15
-30
0
.2
.4
.6
.8
1
TIME (sec)
SLOW HF Waveform
ESD-5 MHz (V/m/Hz)^2
3.0E-14
1.5E-14
0.0E+00
0
.2
.4
.6
.8
1
TIME (sec)


226173133.926 1985
DS Subs RS (40.2 Km)
FAST E Waveform
FAST E (V/m)
30
15
0
-15
-30
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
30
15
0
-15
-30
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
3.0E-14
1.5E-14
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
100
50
0
-50
-100
0
10
20
30
40
TIME (usec)

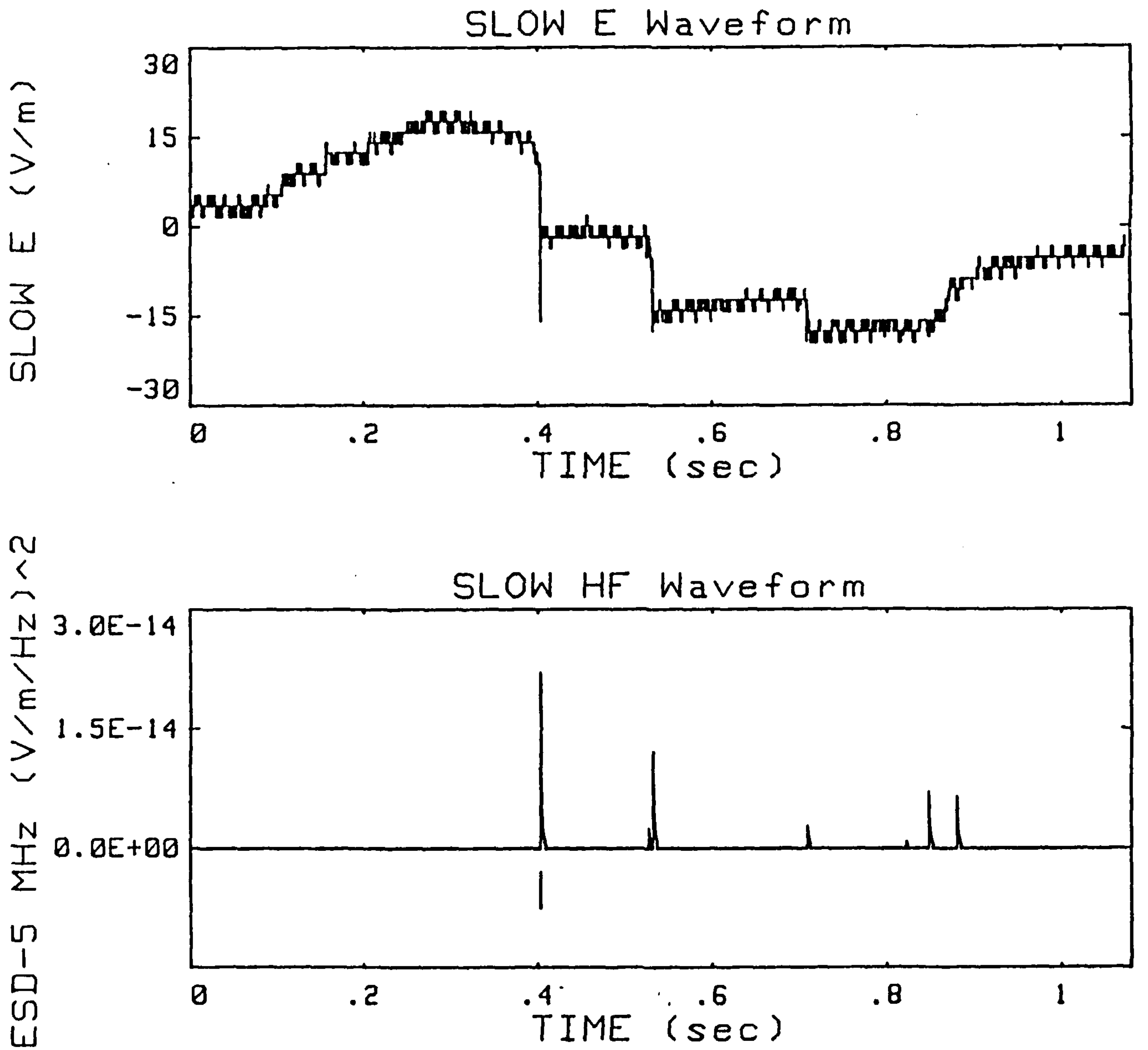
17:31:33.536 14 Aug 1985 (40.2 Km)



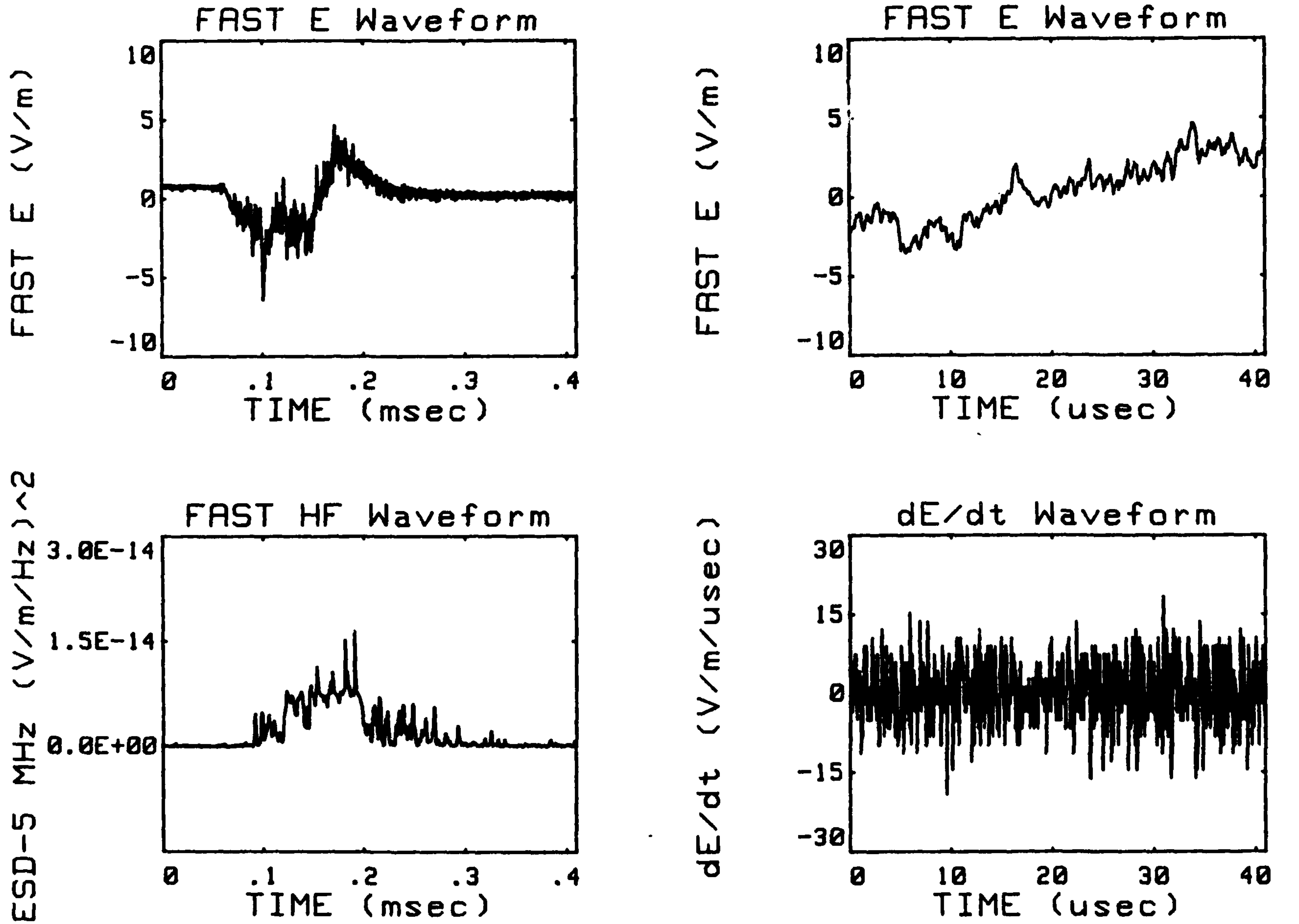
226173156.903 1985 1st RS (42.9 Km)



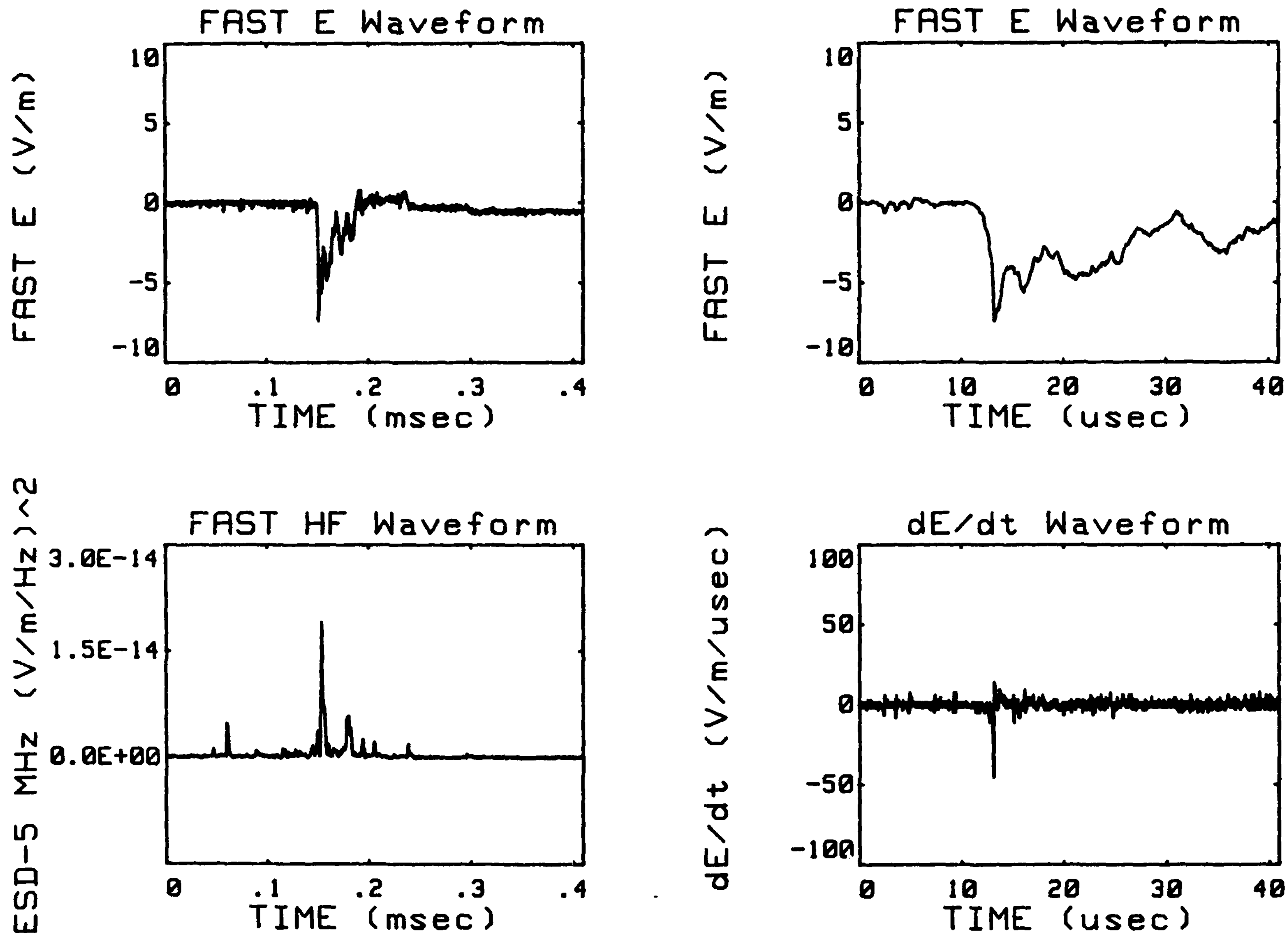
17:31:56.513 14 Aug 1985 (42.9 Km)



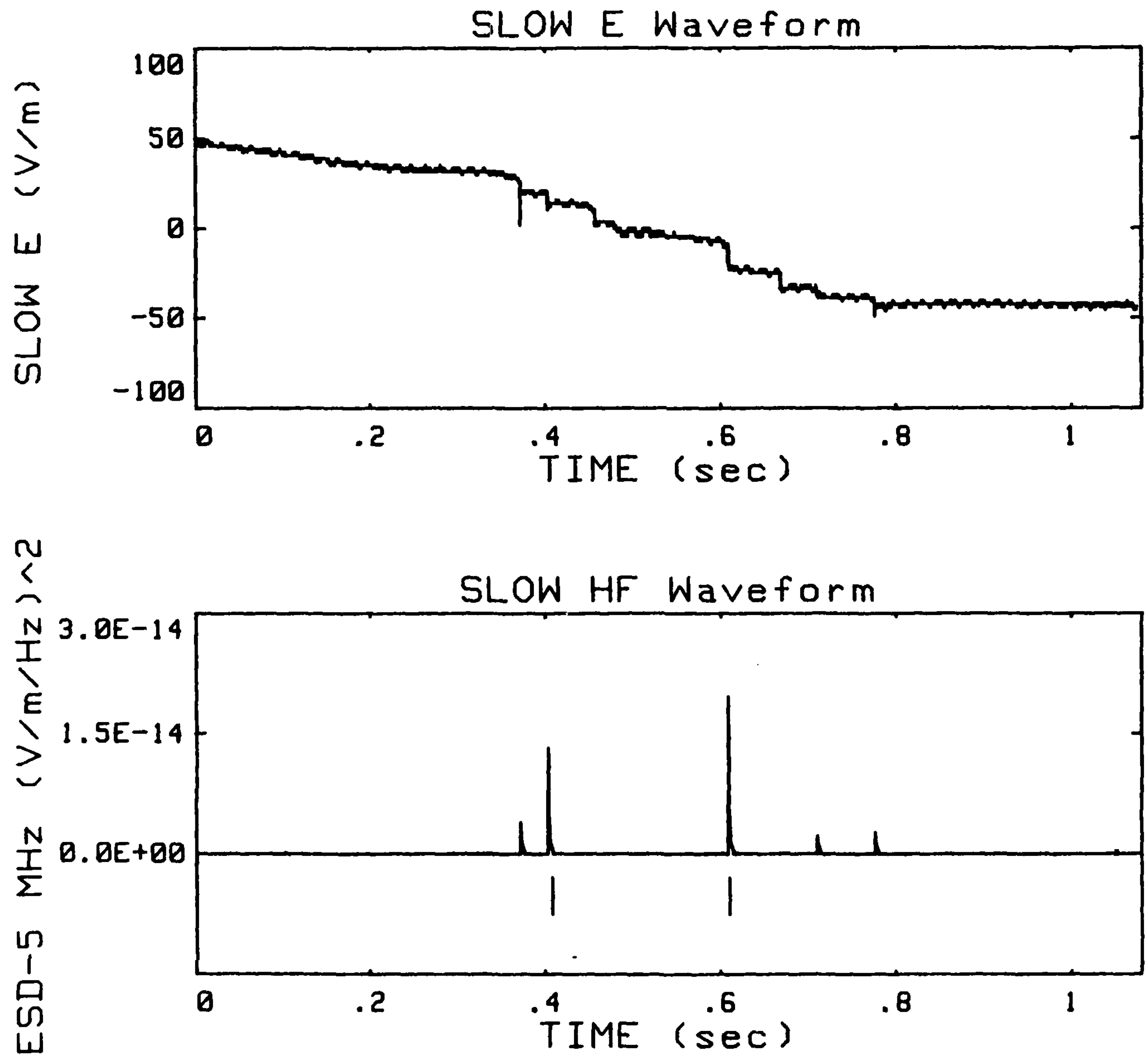
226173216.949   1985   Unknown Cloud   (37.9 Km)



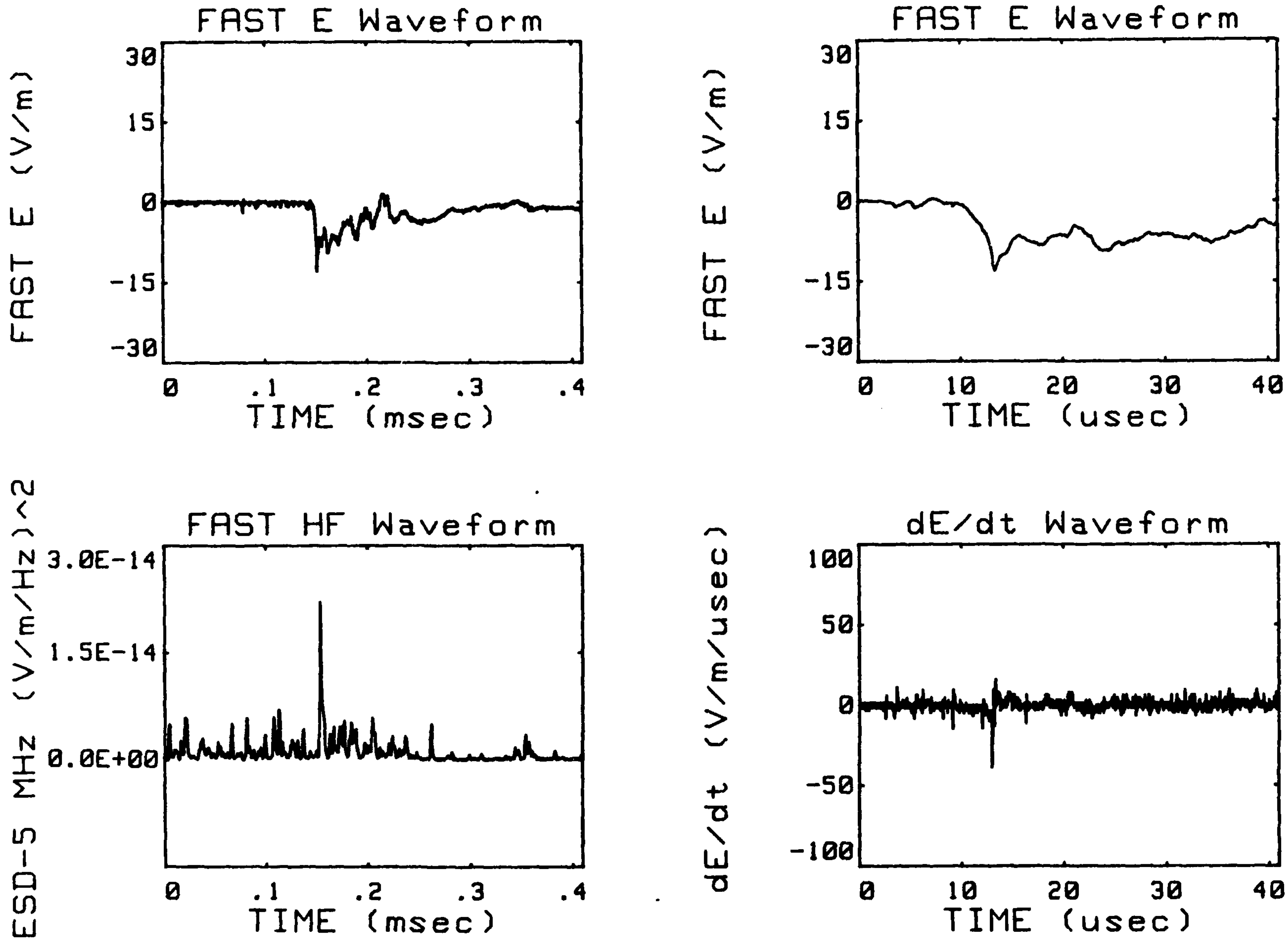
226173217.152 1985 1st RS (37.9 Km)



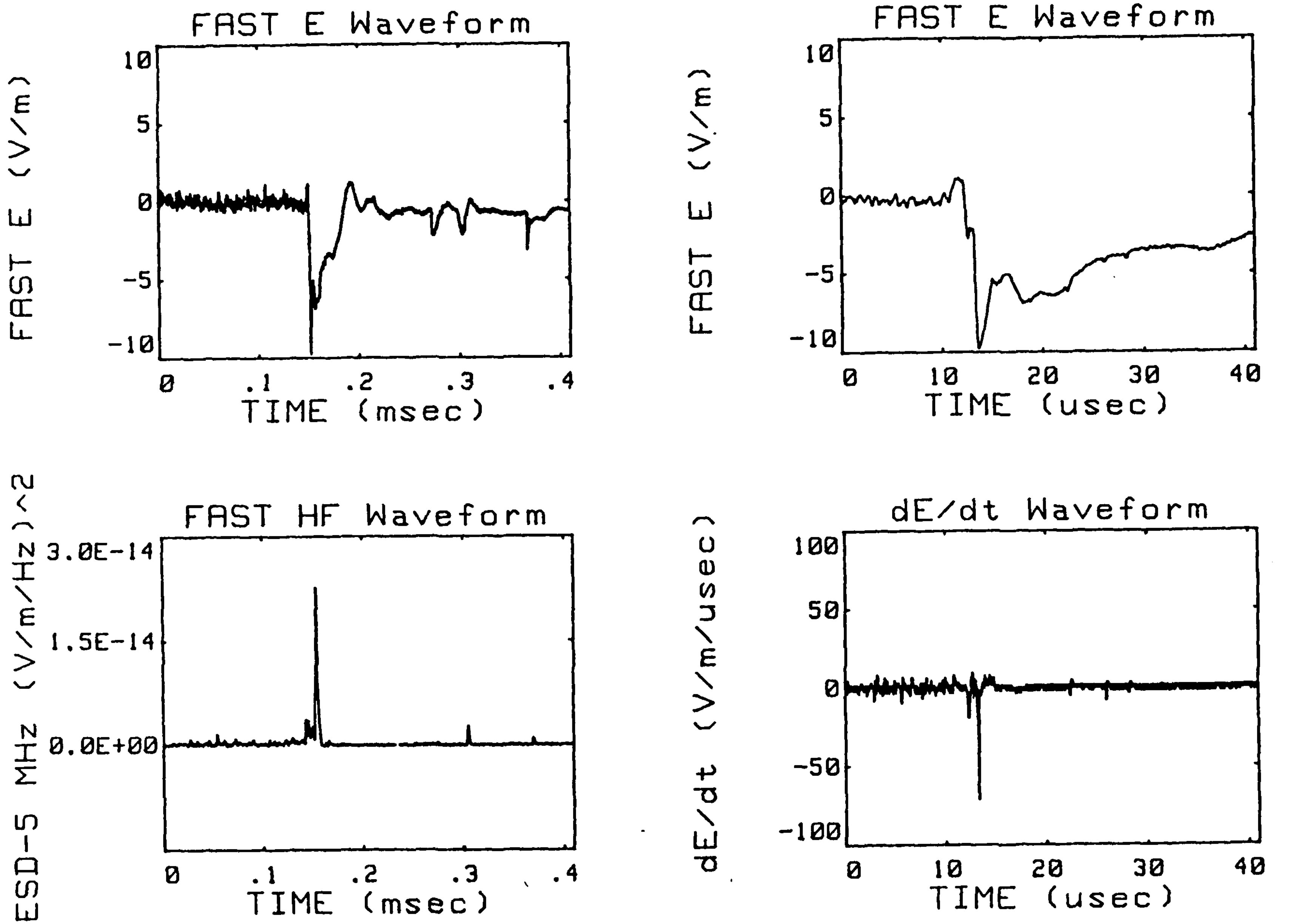
17:32:16.554   14 Aug 1985   (37.9 Km)



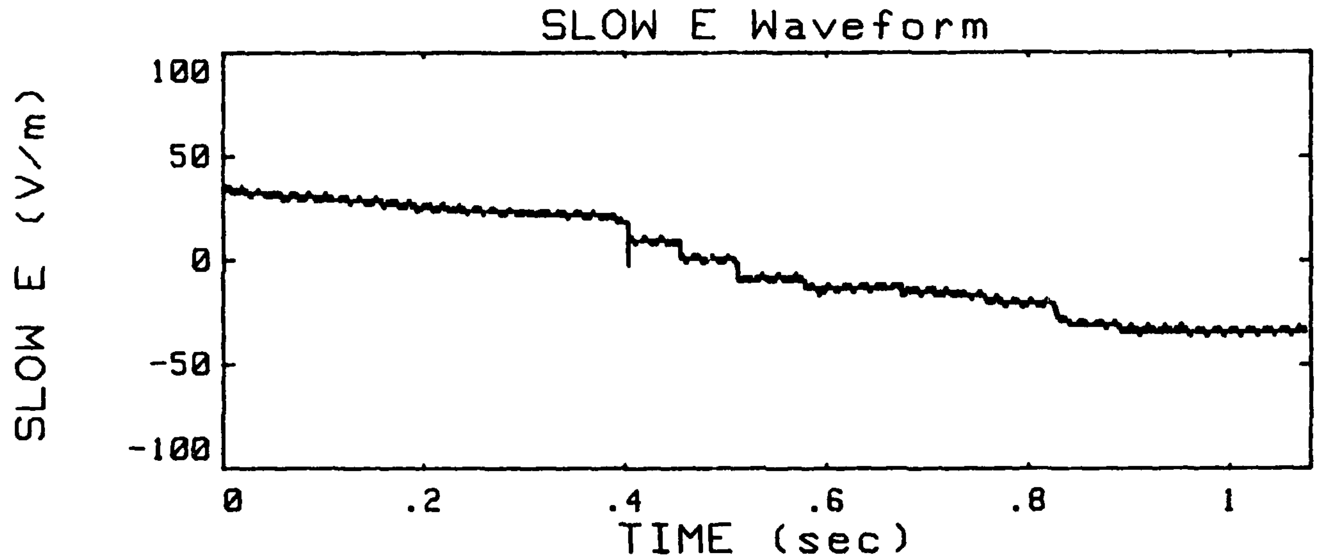
226173244.098   1985   1st RS   (38.8   Km)

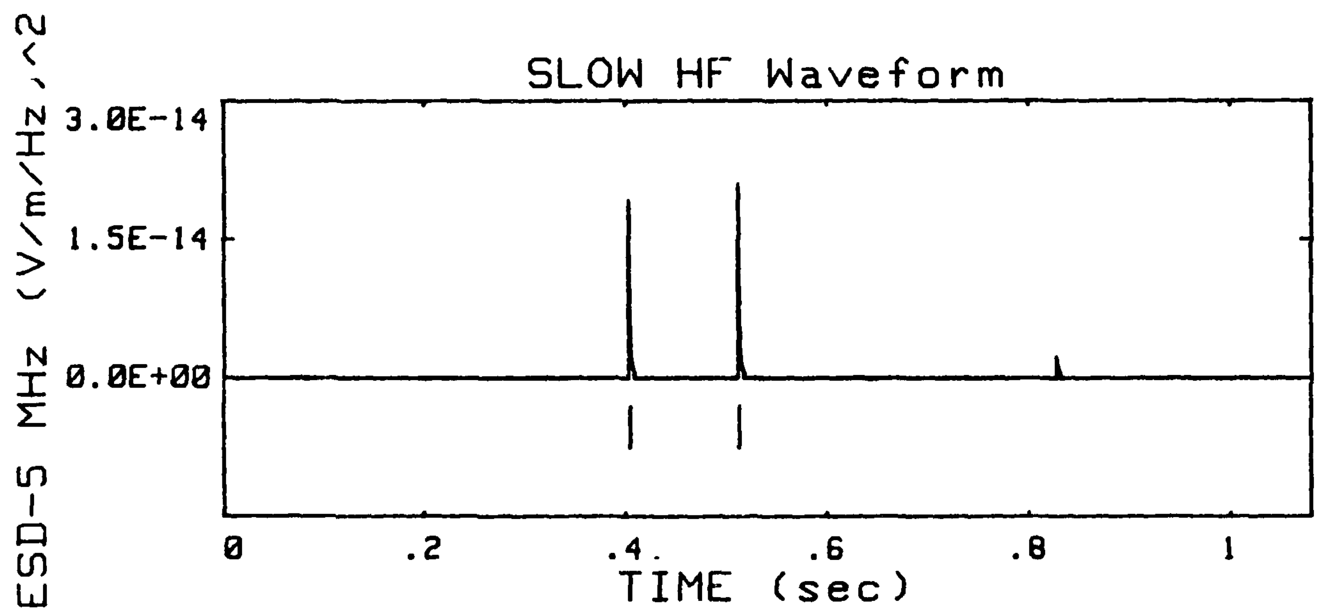


226173244.207 1985 Chaotic Subs RS (38.8 Km)

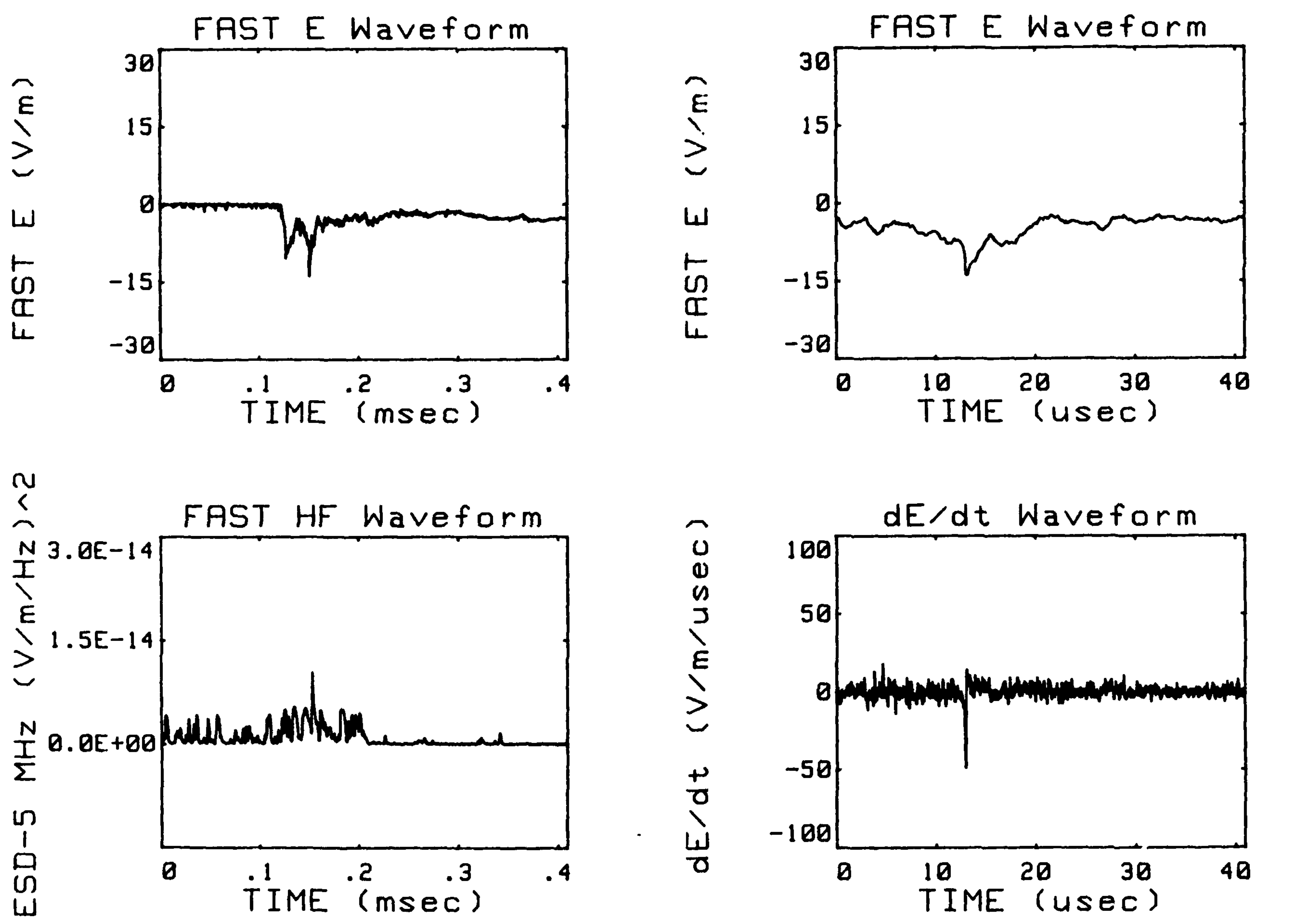


17:32:43.706 14 Aug 1985 (38.8 Km)

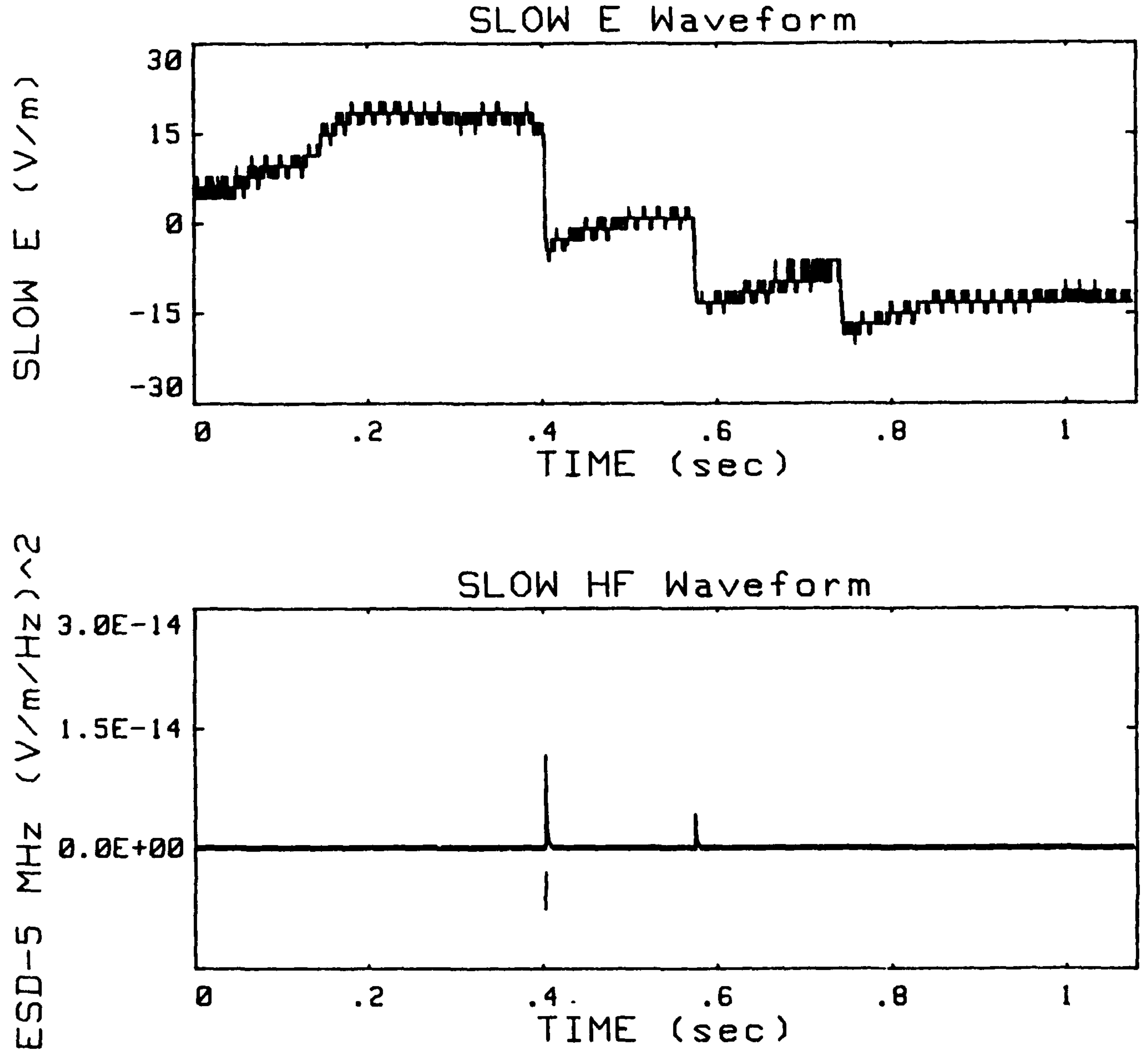




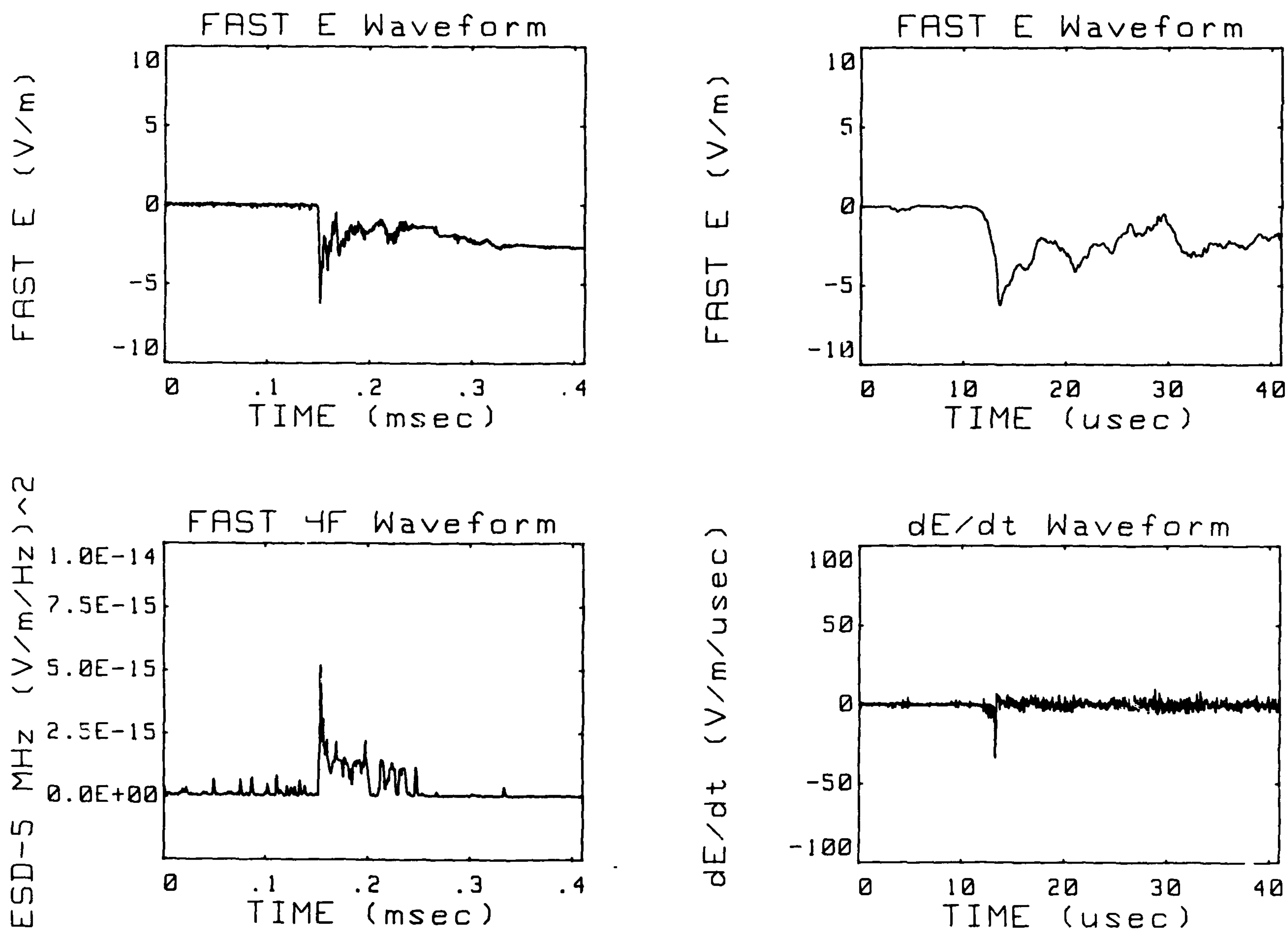
226173323.656 1985 Multiple Gnd RS (31.1 Km)



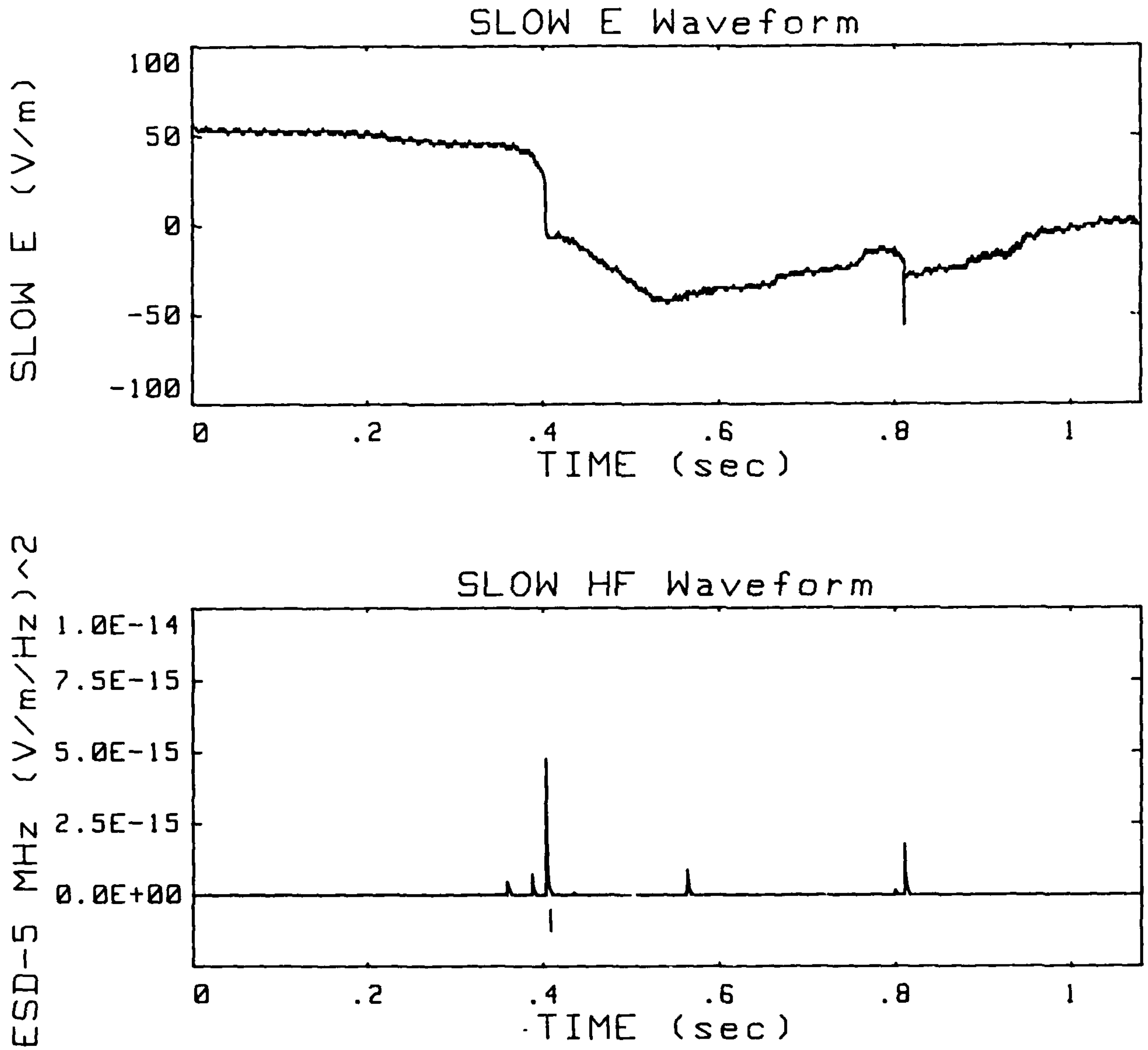
17:33:23.266 14 Aug 1985 (31.1 Km)



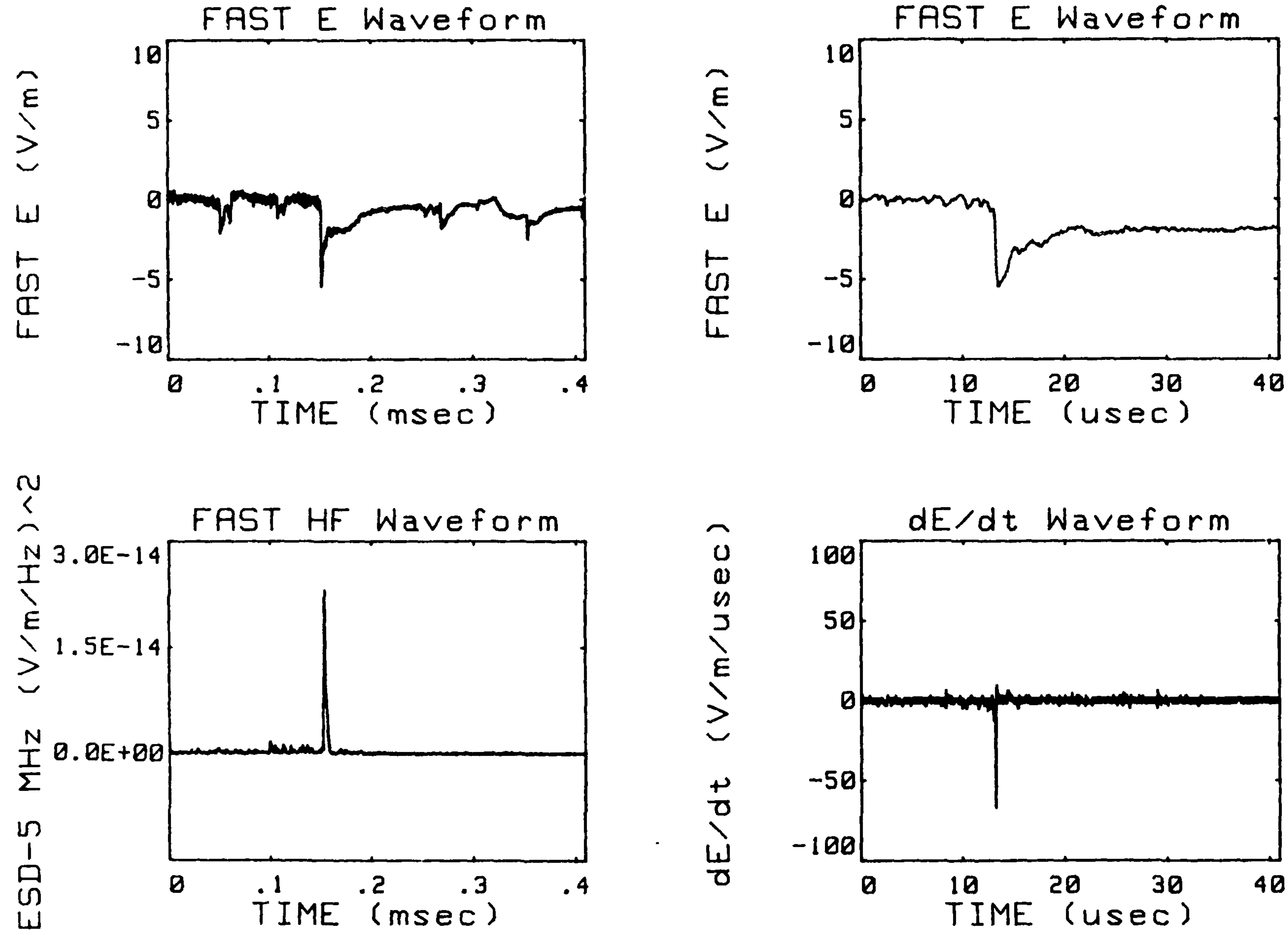
226173403.828 1985 1st RS (16.7 Km)



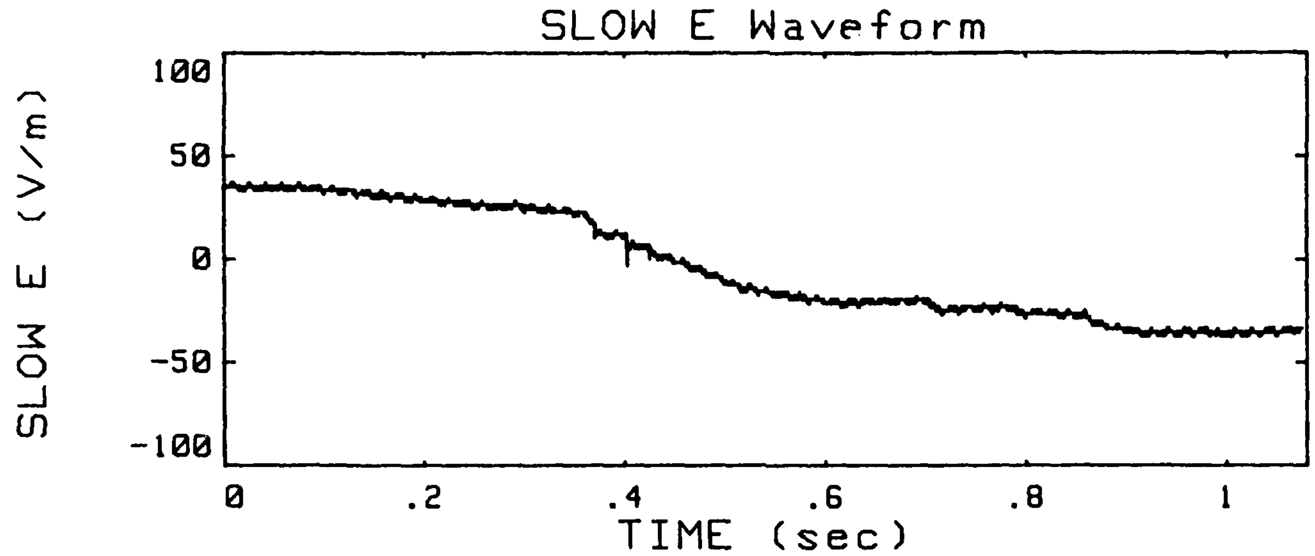
17:34:03.432 14 Aug 1985 (16.7 Km)

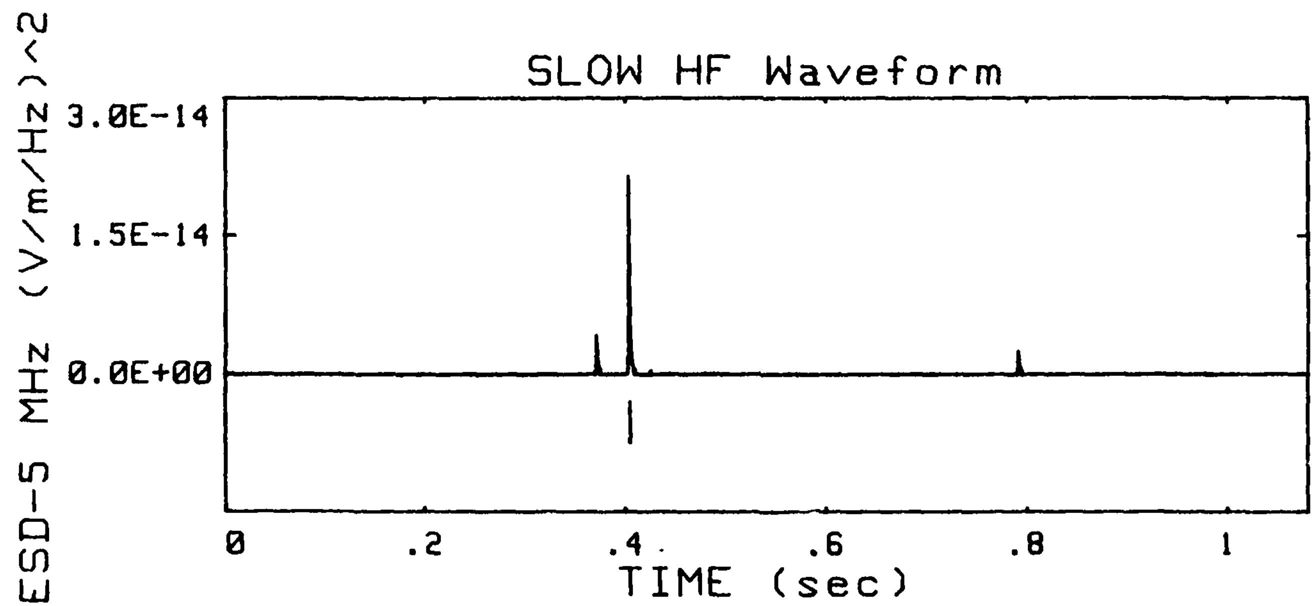


226173540.063 1985 DS Subs RS (38.4 Km)

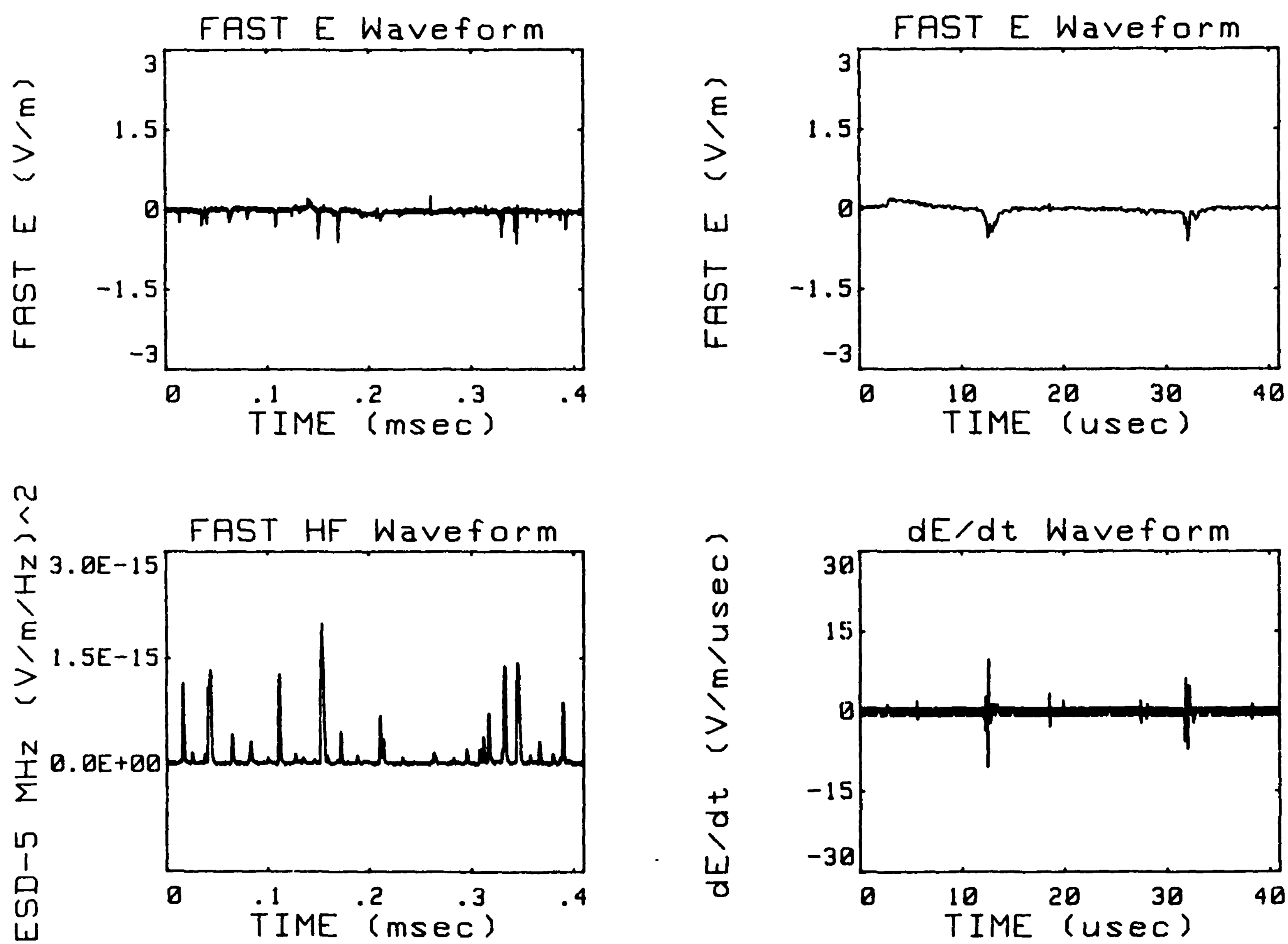


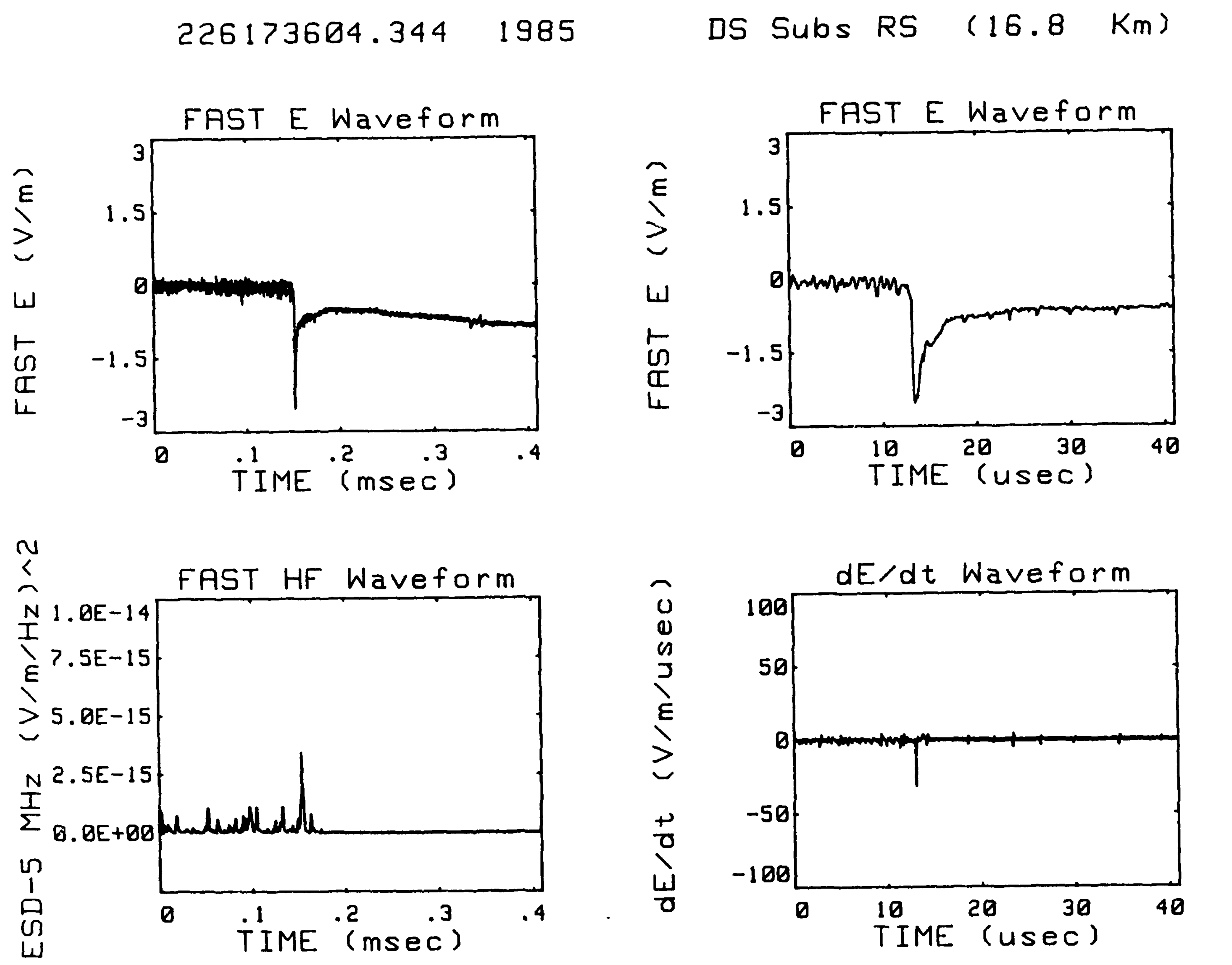
17:35:39.671 14 Aug 1985 (38.4 Km)



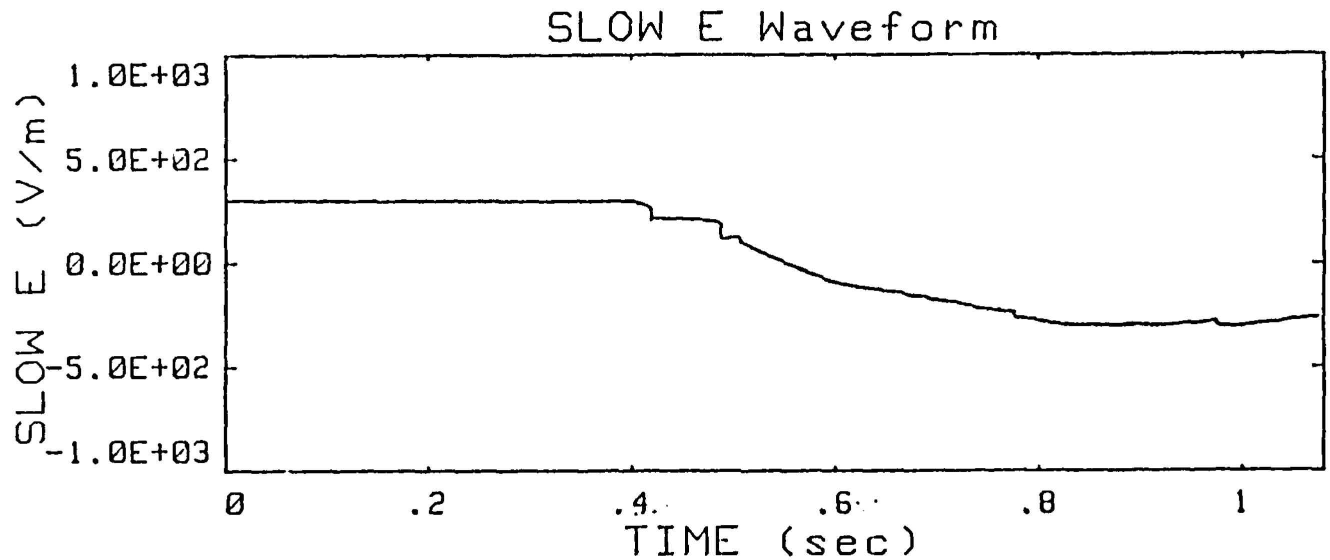


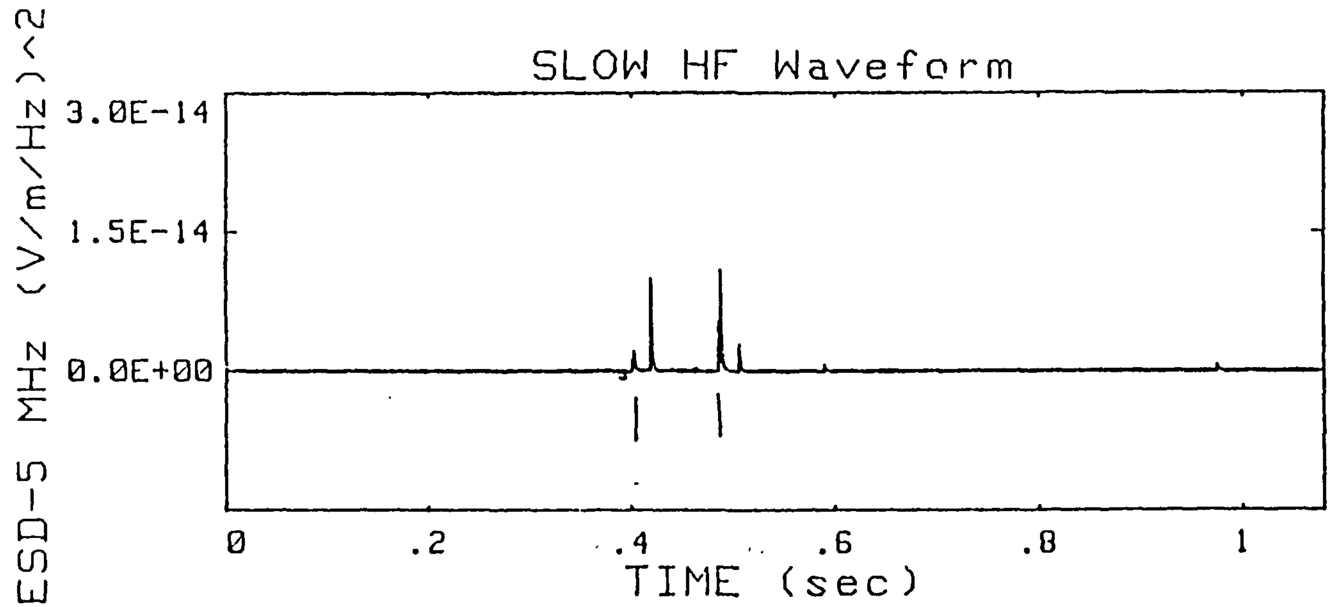
226173604.241 1985 Char Cloud Pulse (16.8 Km)



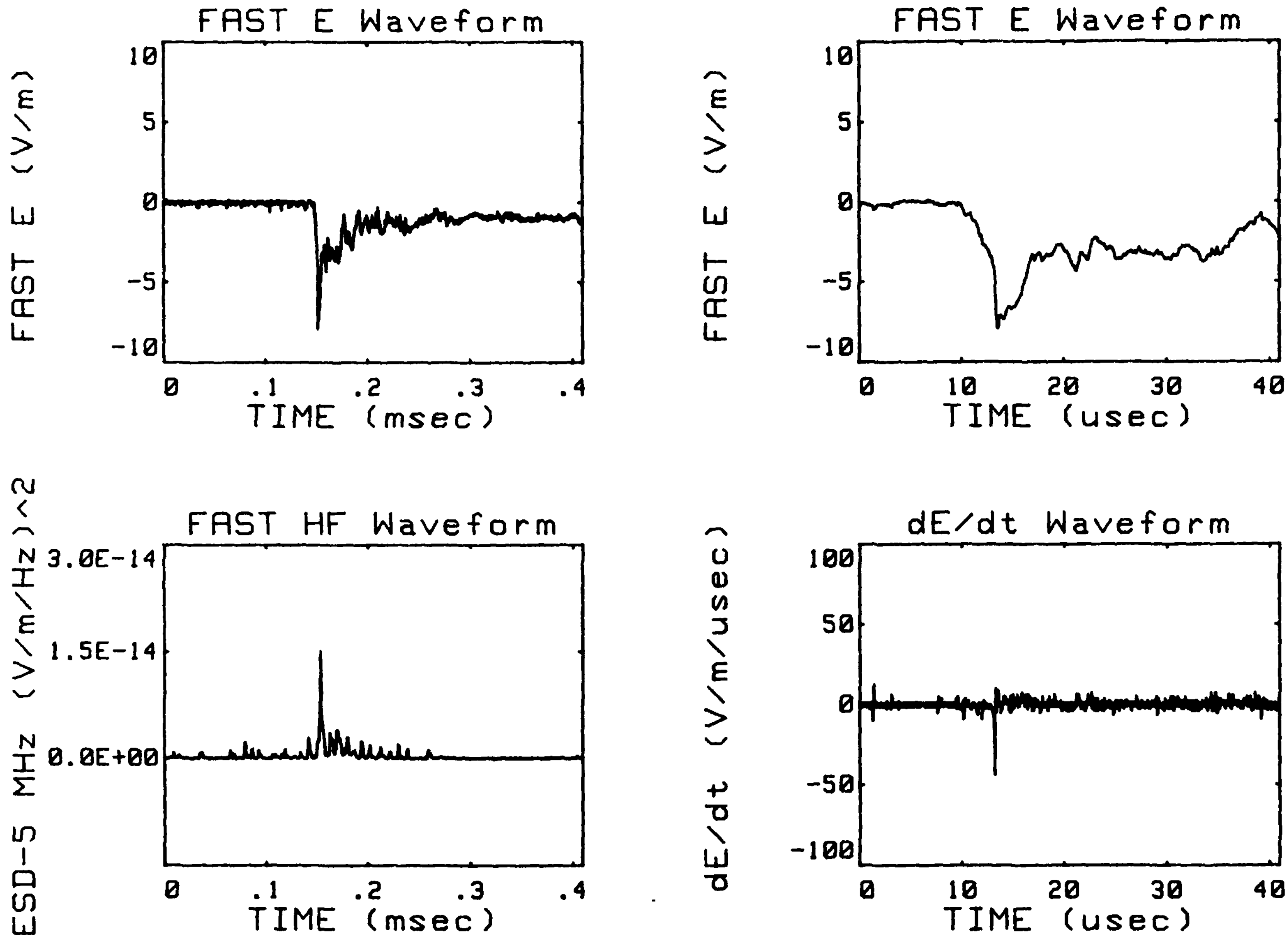

226173604.344 1985
DS Subs RS (16.8 Km)
FAST E Waveform
FAST E (V/m)
3
1.5
0
-1.5
-3
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
3
1.5
0
-1.5
-3
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
1.0E-14
7.5E-15
5.0E-15
2.5E-15
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
100
50
0
-50
-100
0
10
20
30
40
TIME (usec)

17:36:03.850 14 Aug 1985 (16.8 Km)

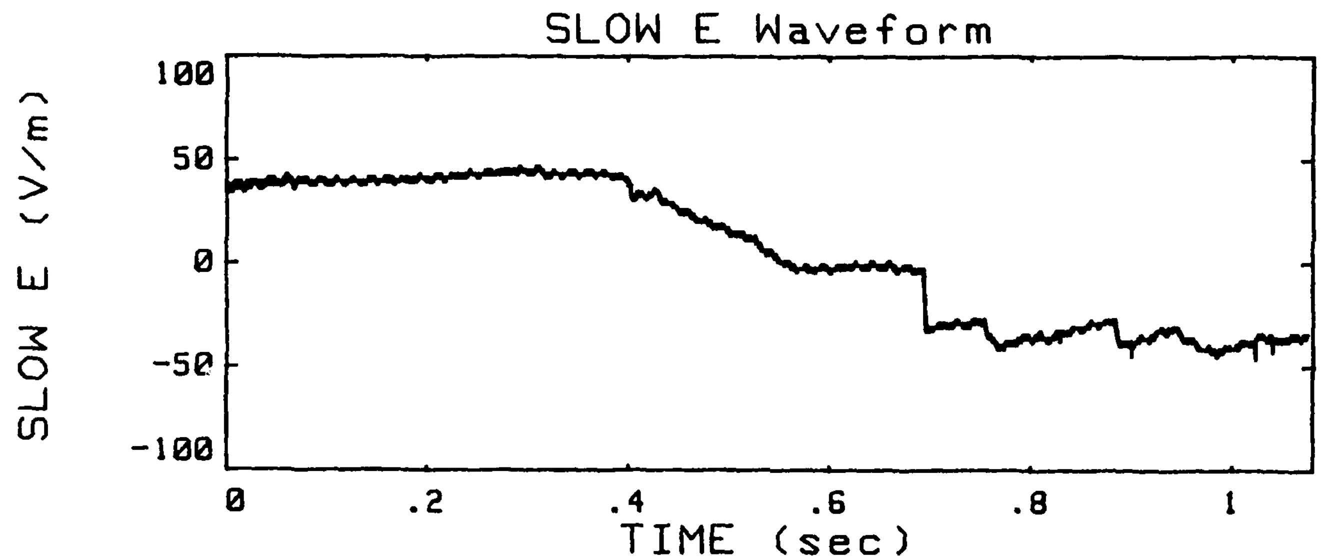


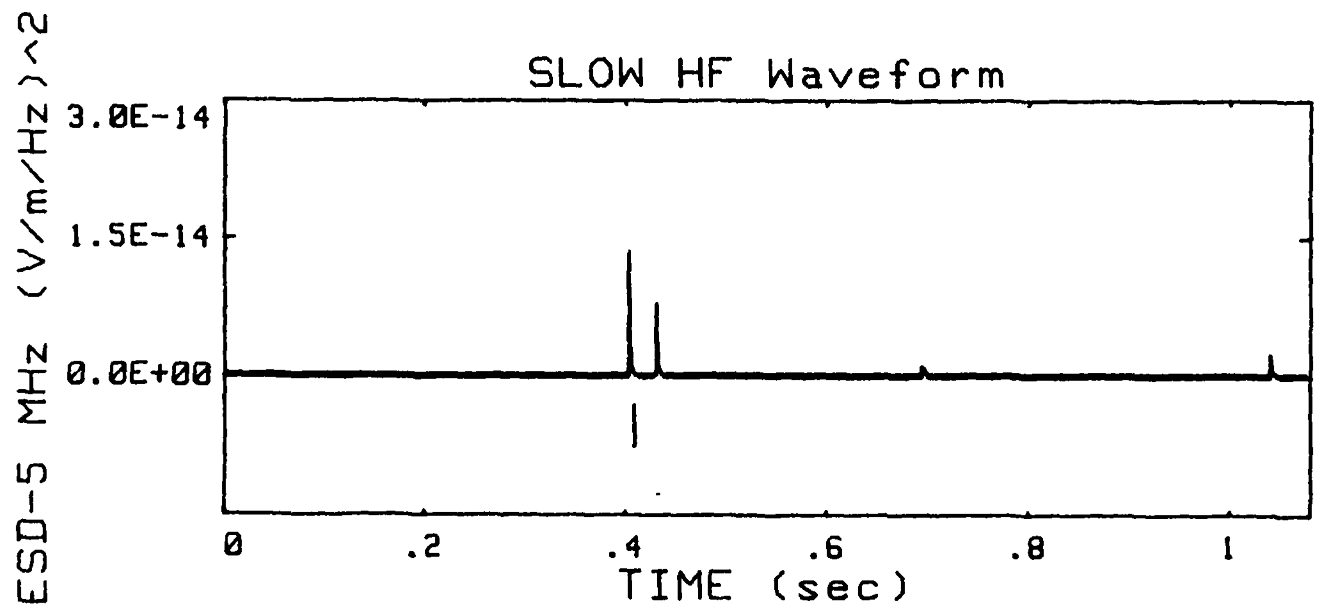


226173618.999 1985 1st RS (30.8 Km)

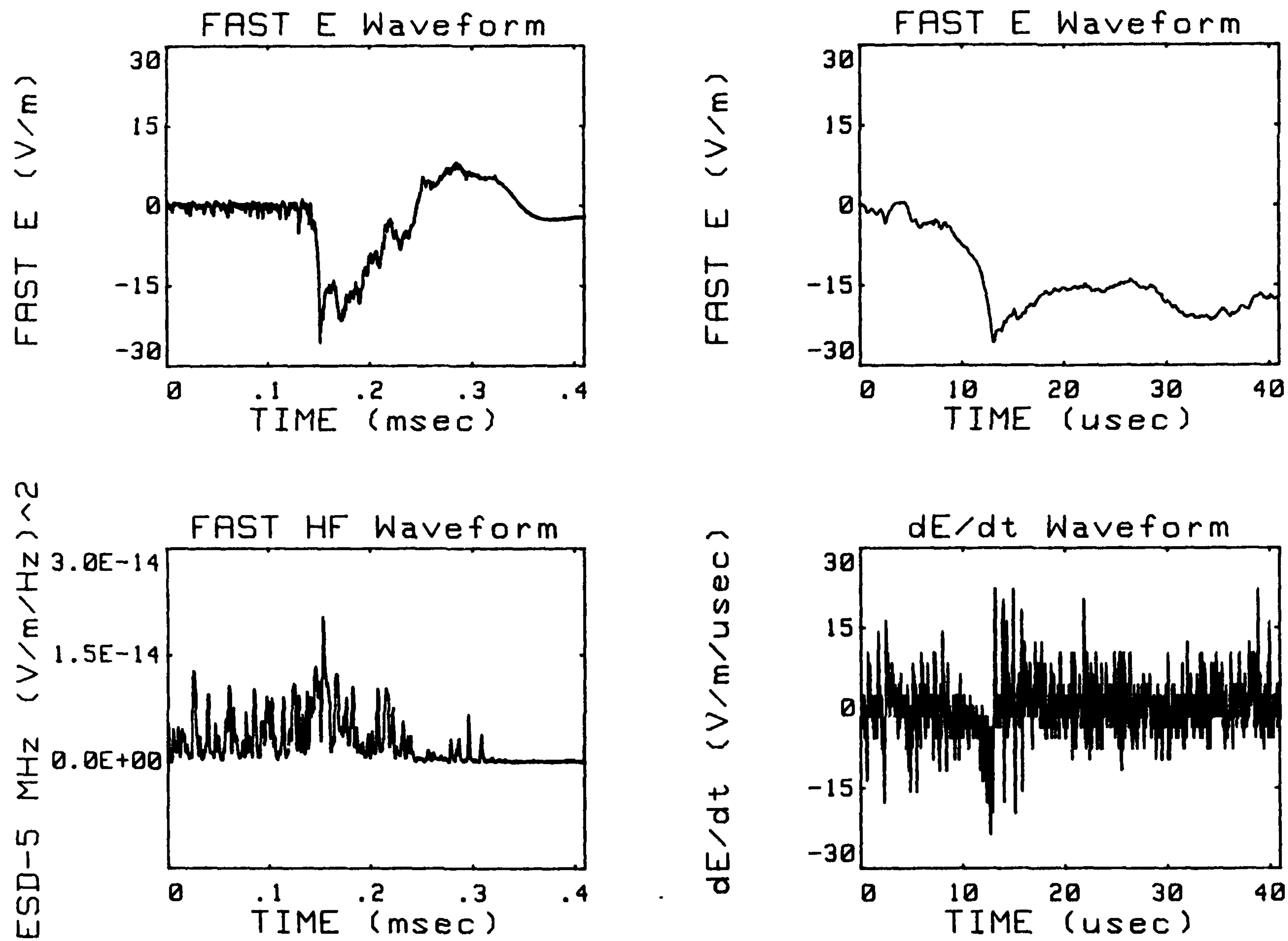


17:36:18.603 14 Aug 1985 (30.8 Km)

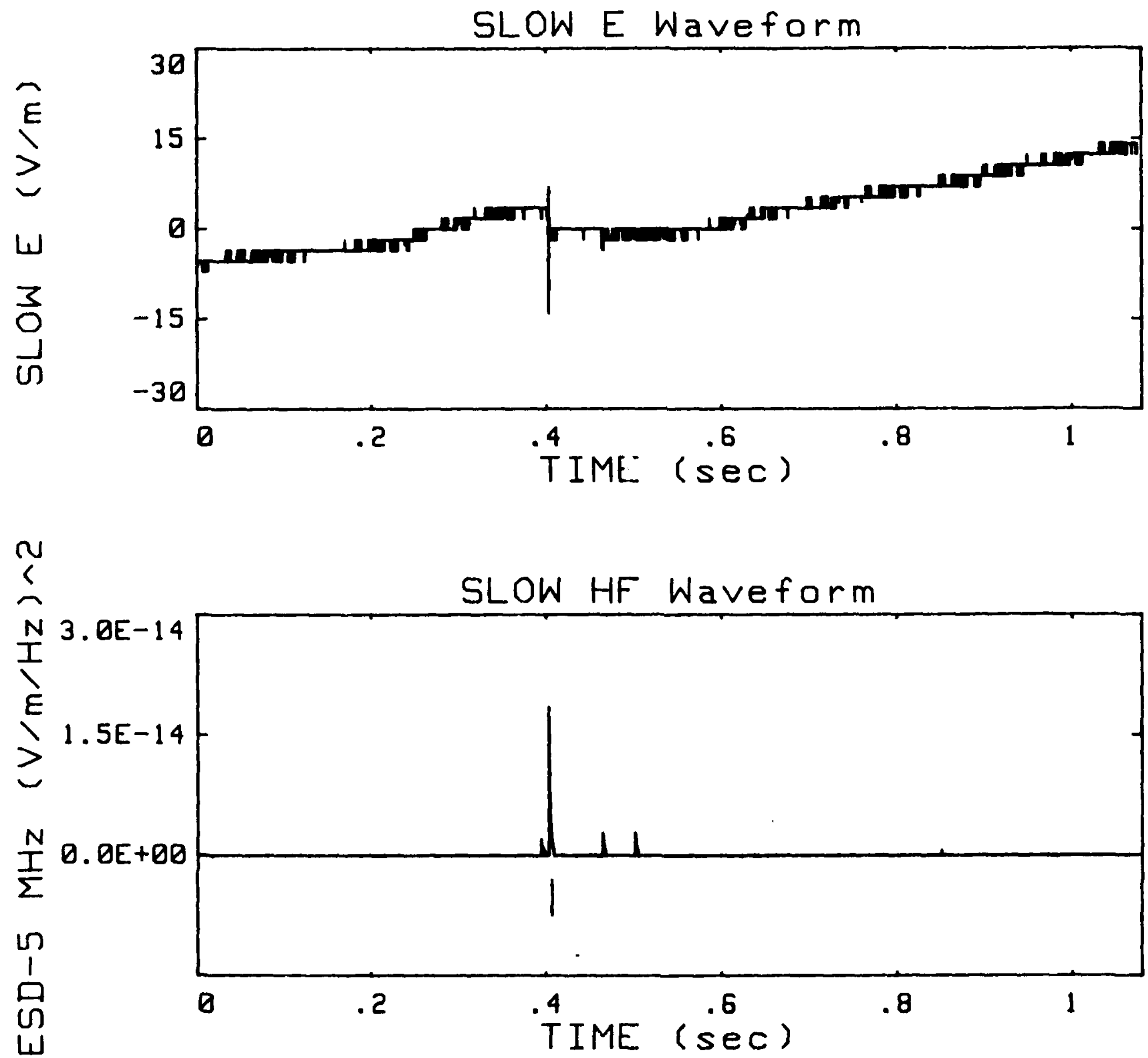




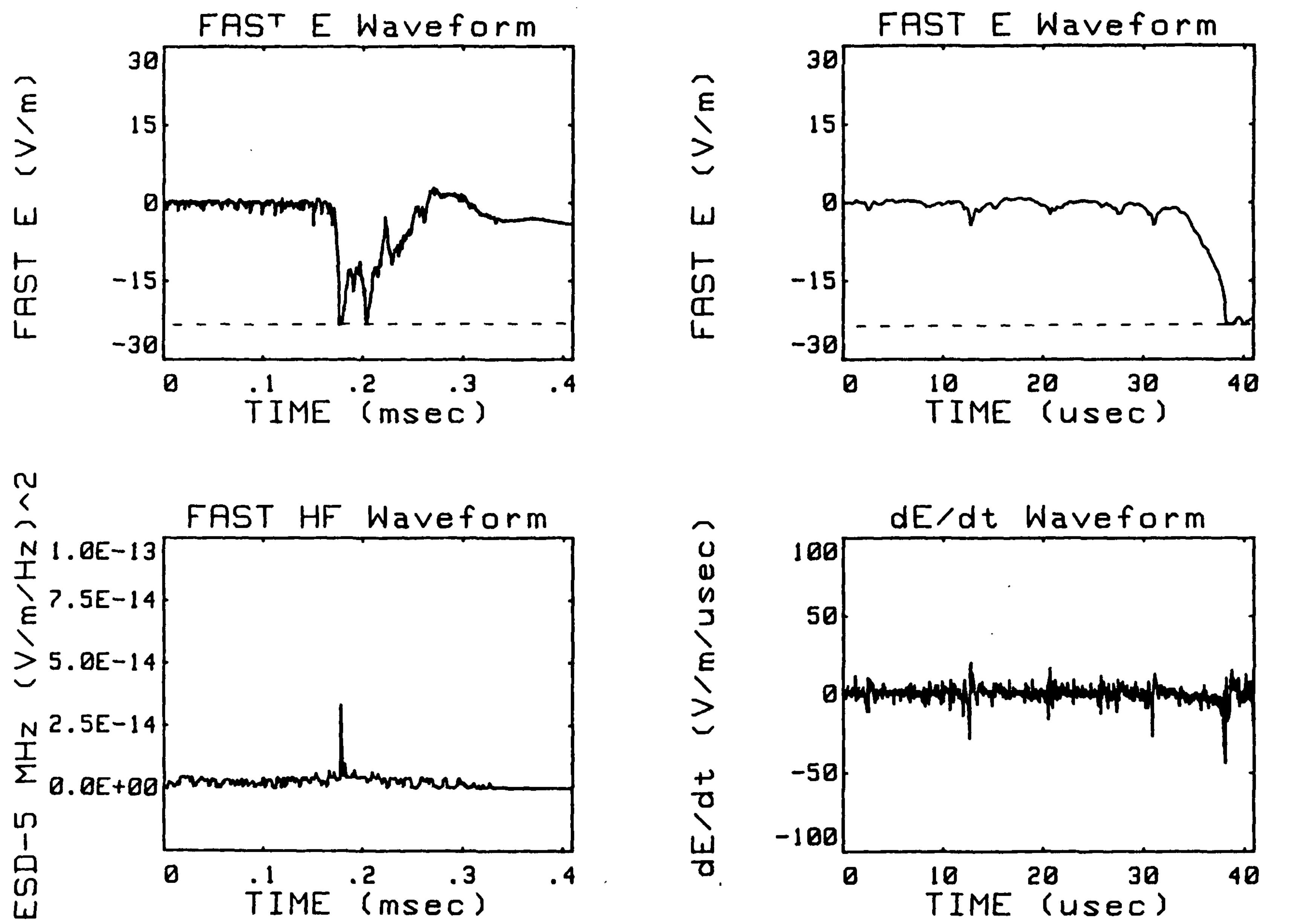
226174430.986 1985 1st RS (48.3 Km)



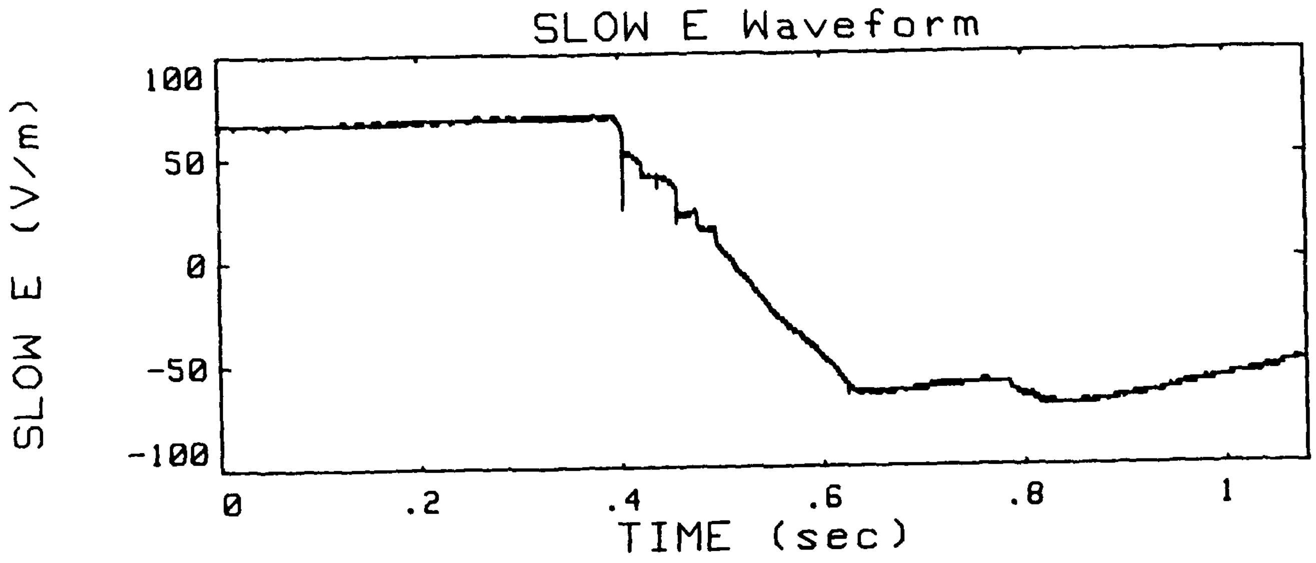
17:44:30.592 14 Aug 1985 (48.3 Km)

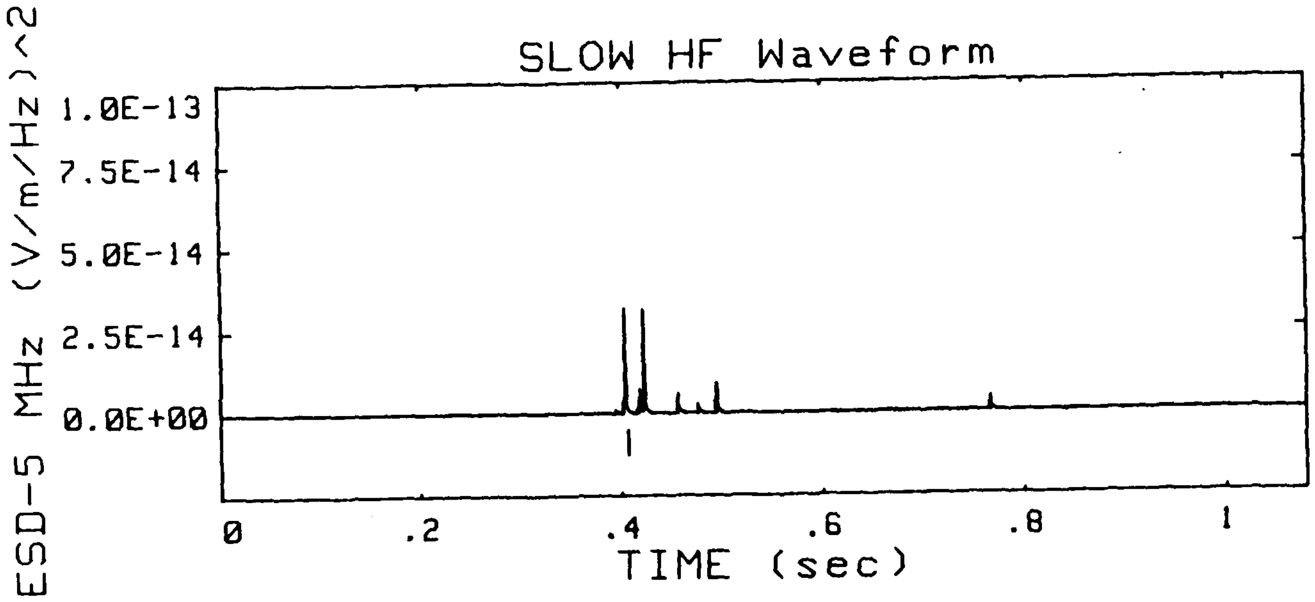


226174436.078 1985 1st RS (28.9 Km)

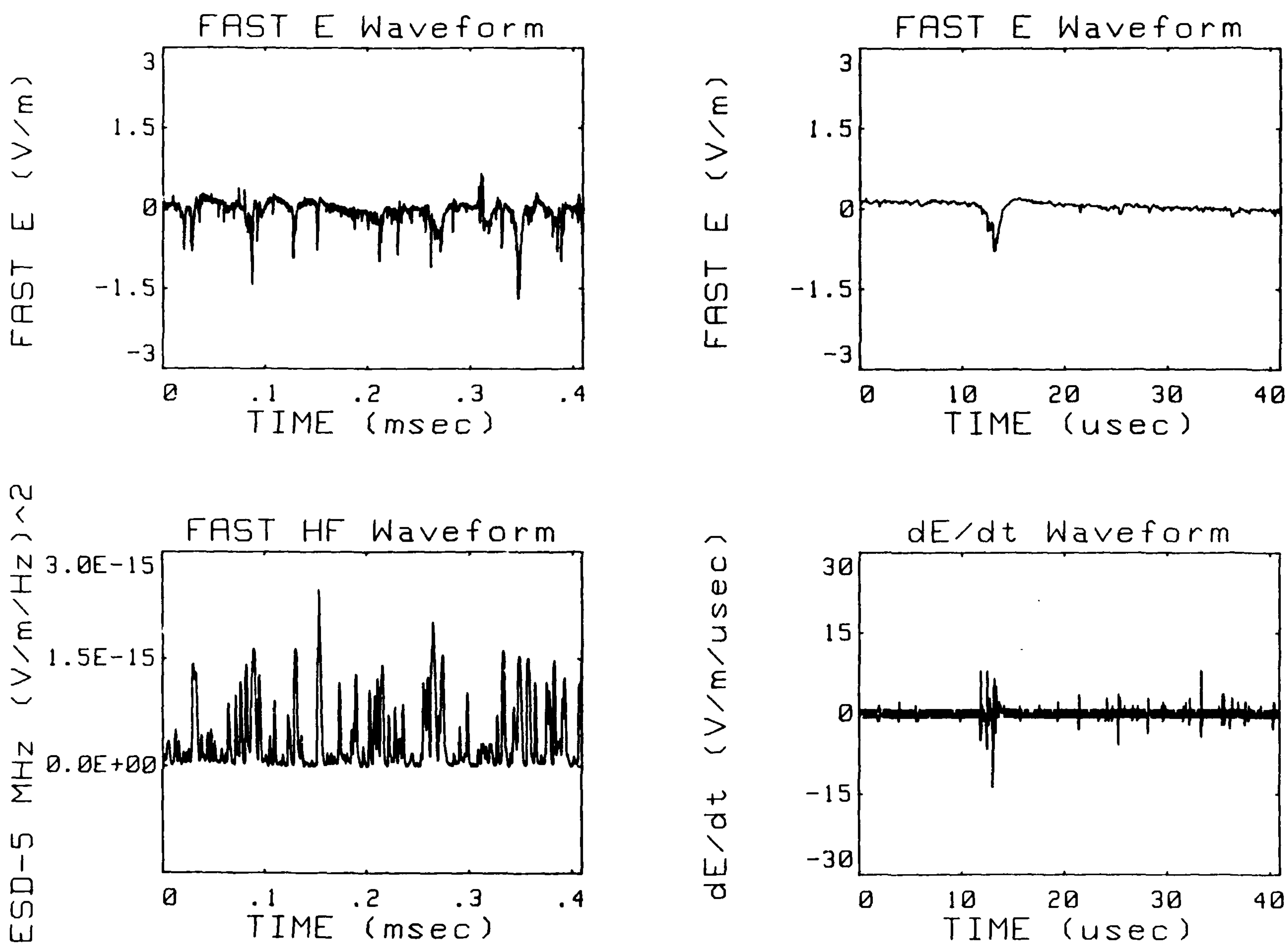


17:44:35.684 14 Aug 1985 (28.9 Km)

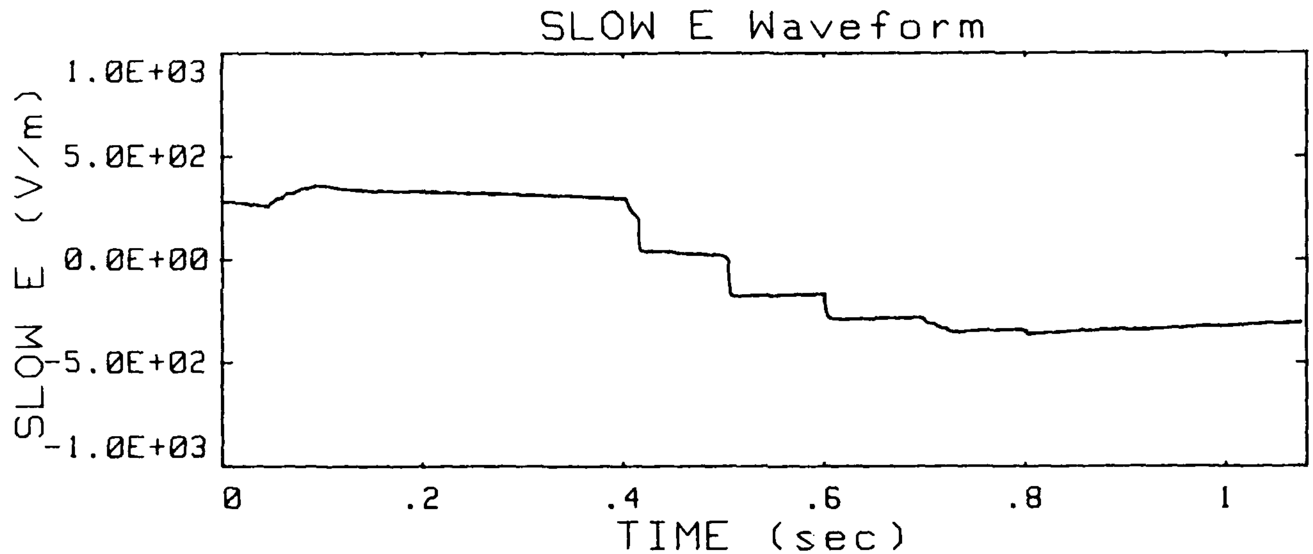


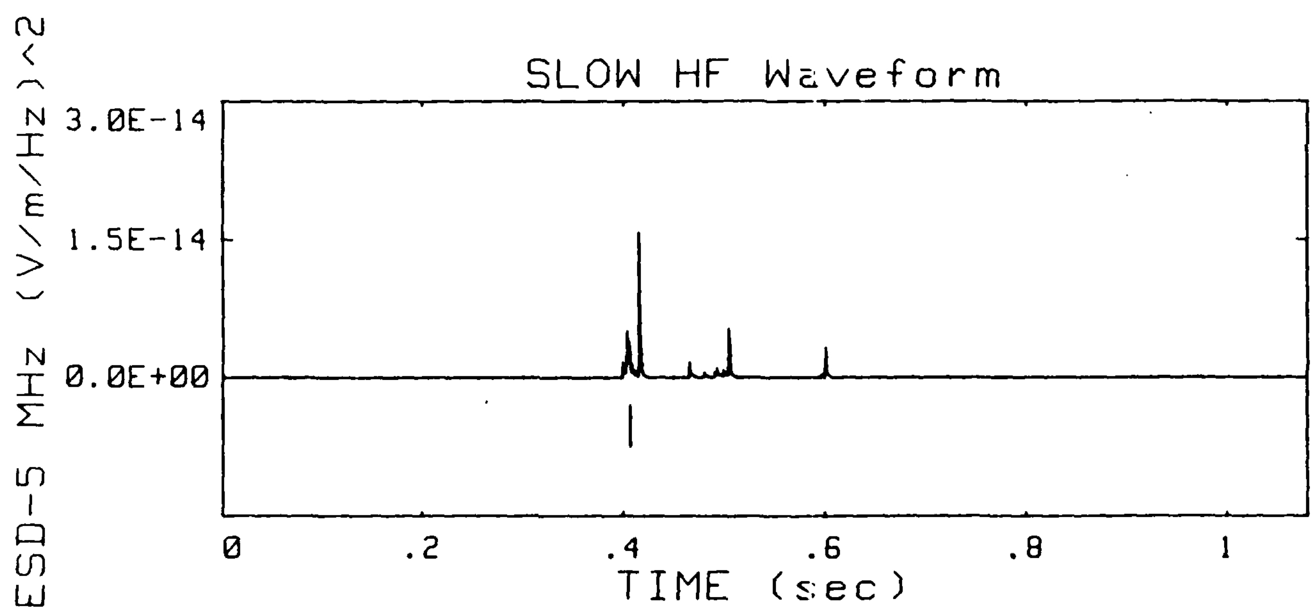


226174504.511 1985 Char Cloud Pulse (17.5 Km)

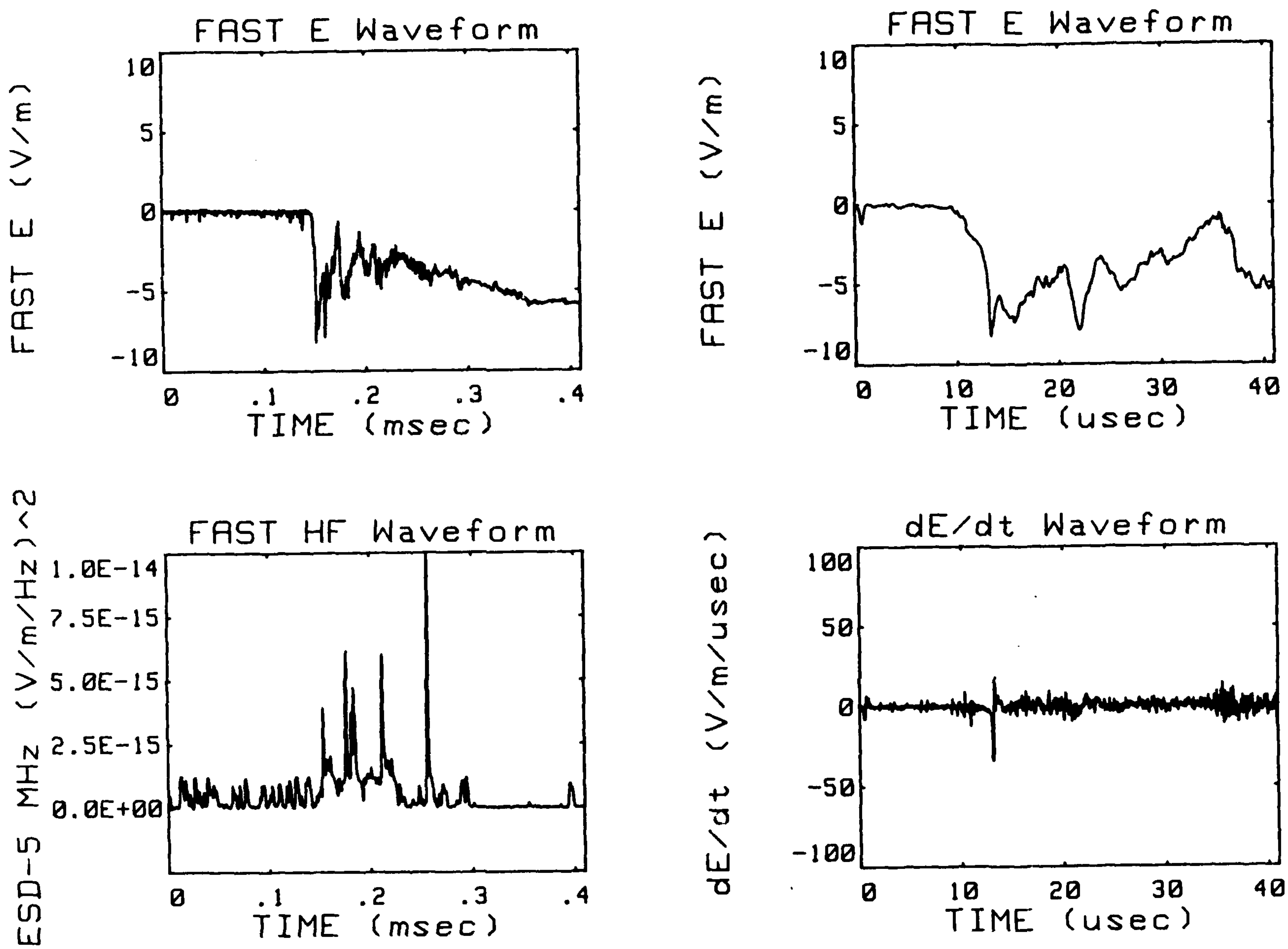


17:45:04.117 14 Aug 1985 (17.5 Km)

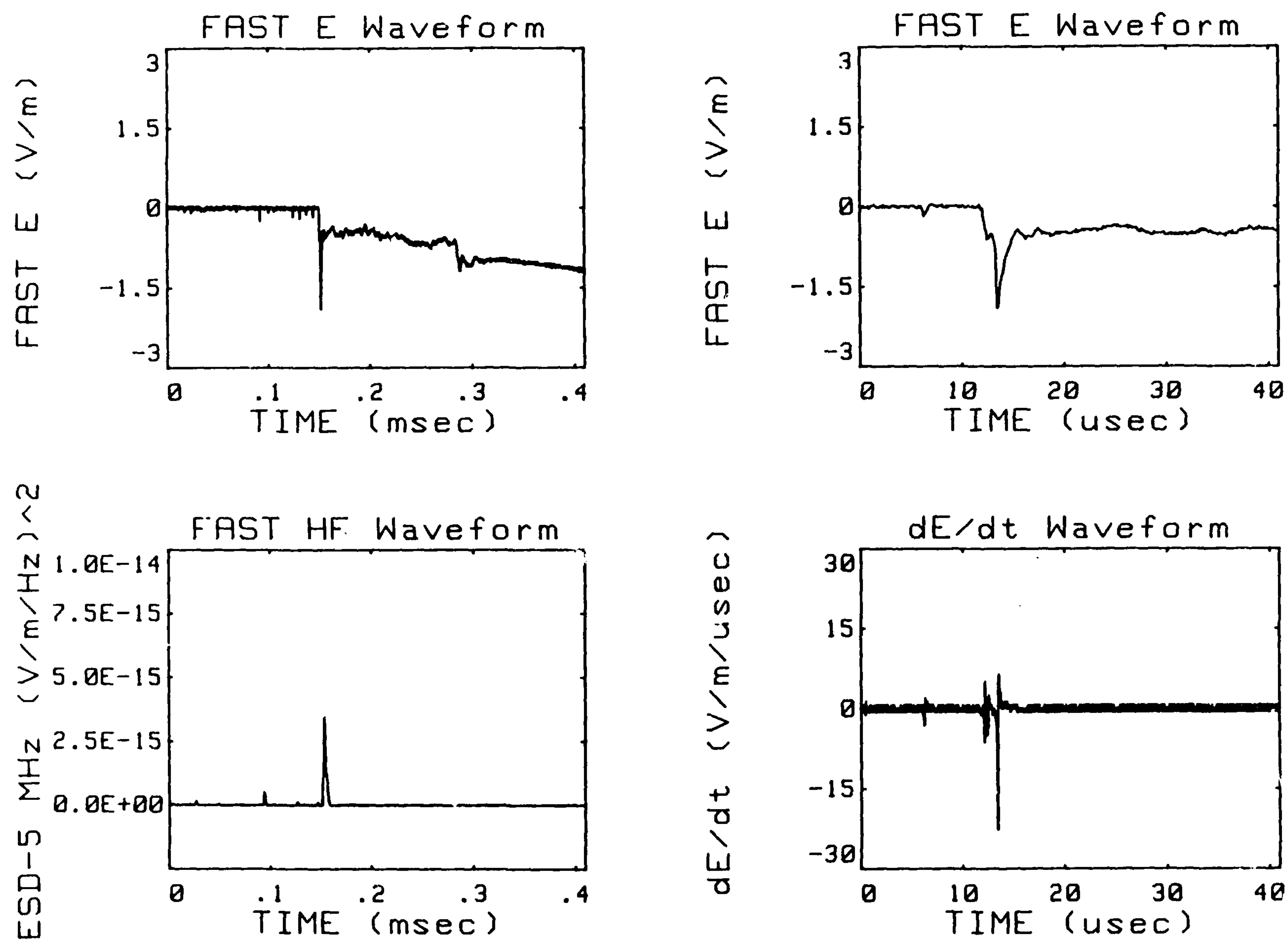




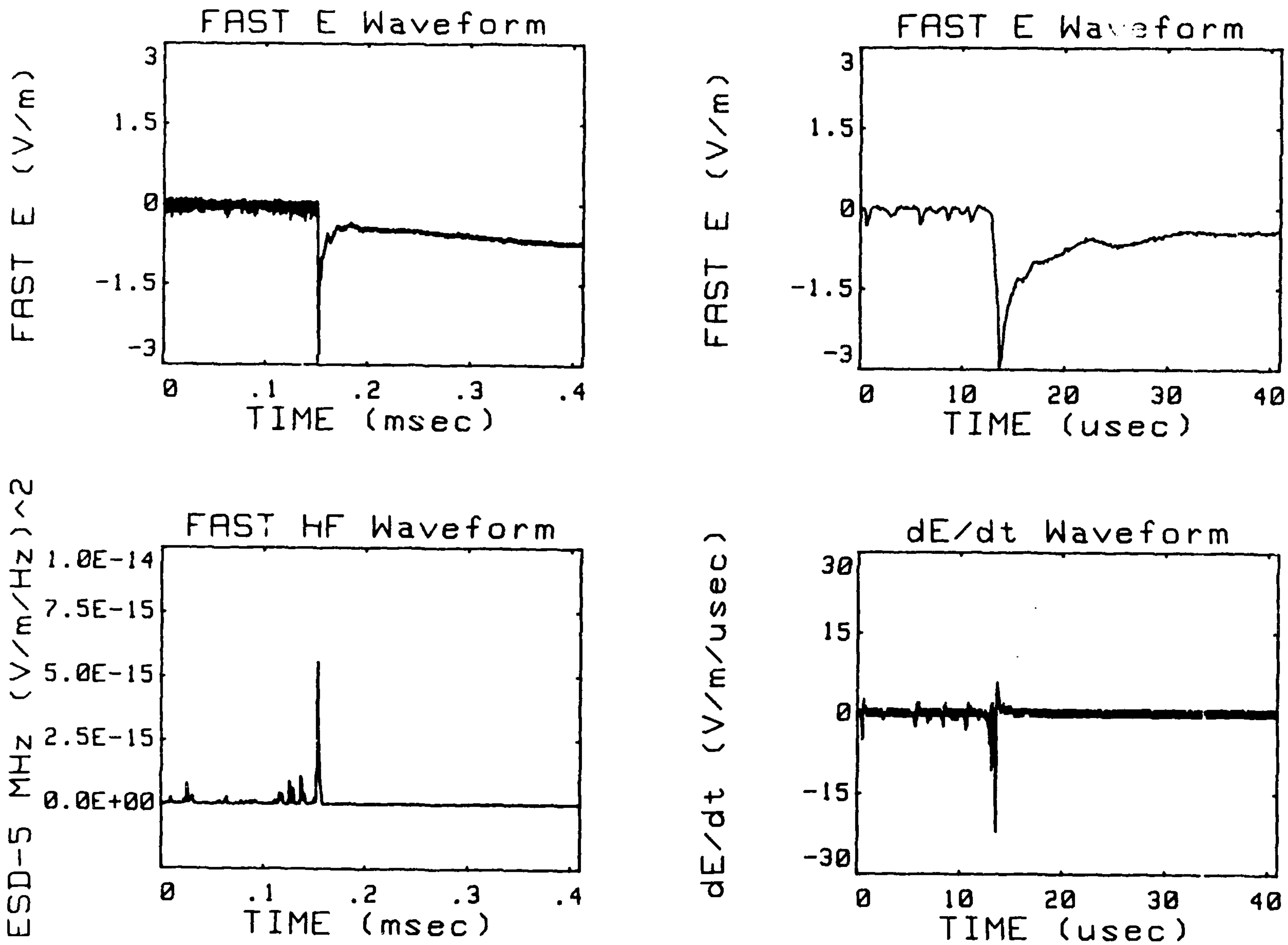
226174528.485 1985 1st RS (15.3 Km)



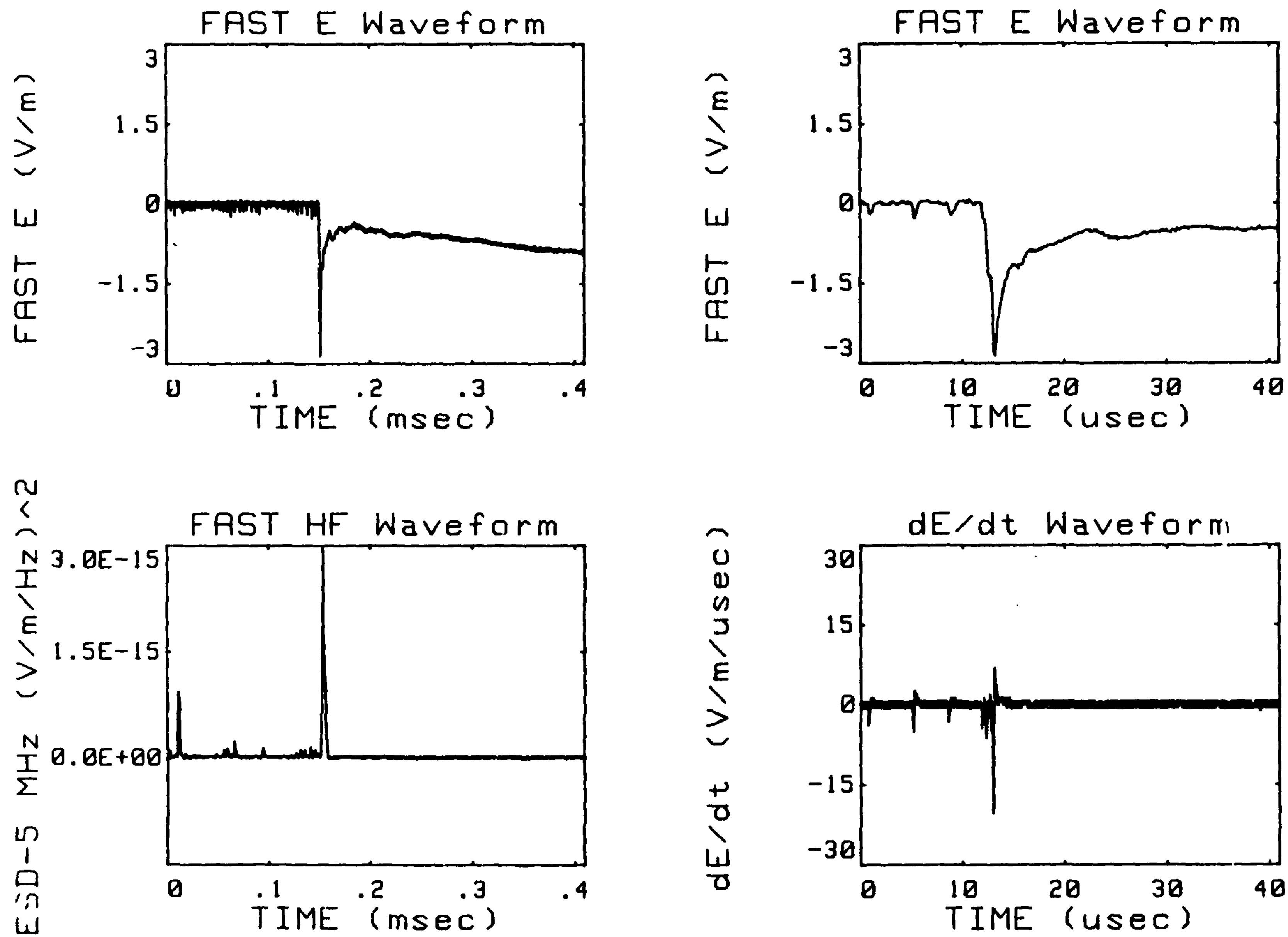
226174528.684 1985 DS Subs RS (15.3 Km)



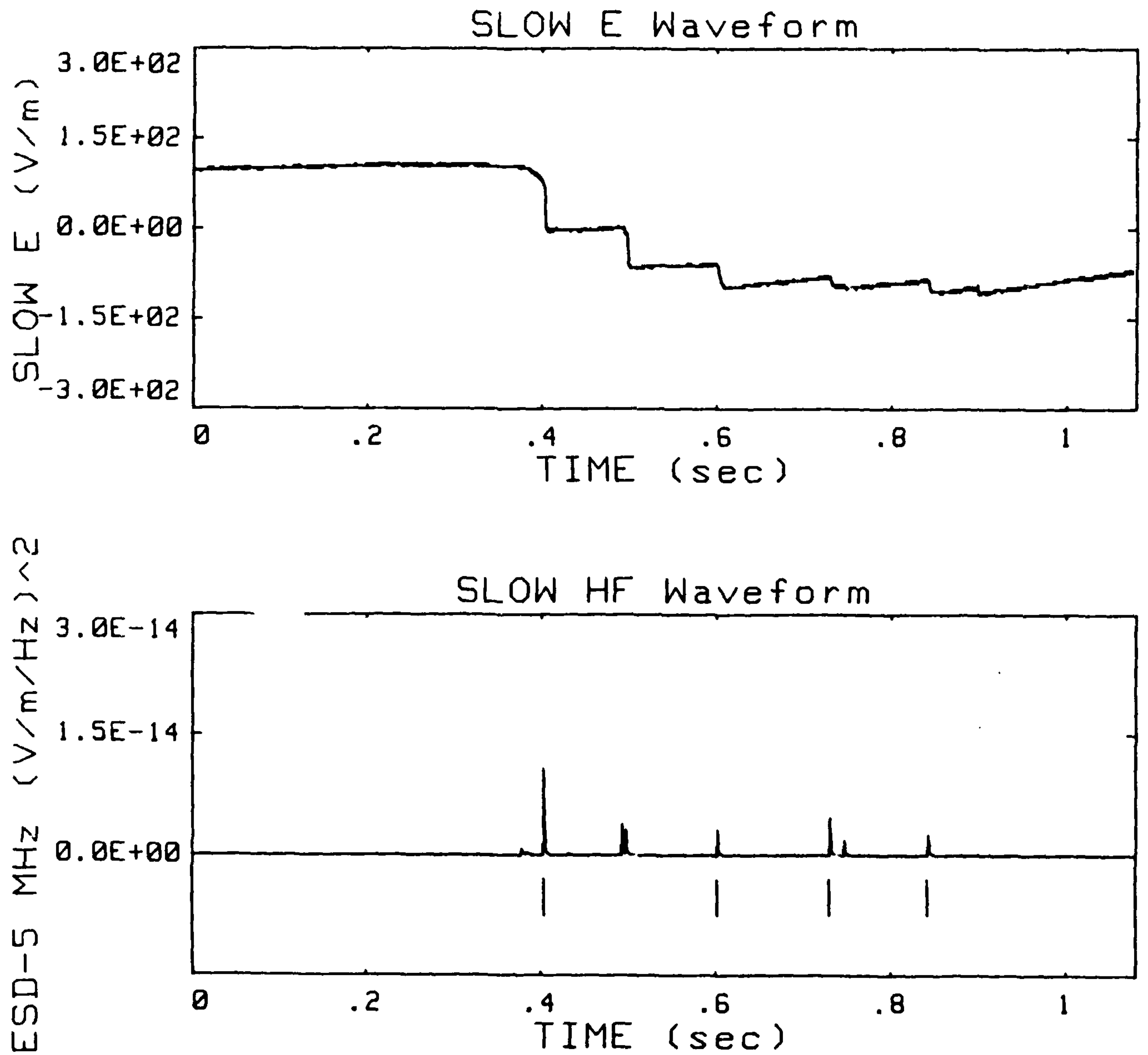
226174528.812 1985 DS Subs RS (15.3 Km)



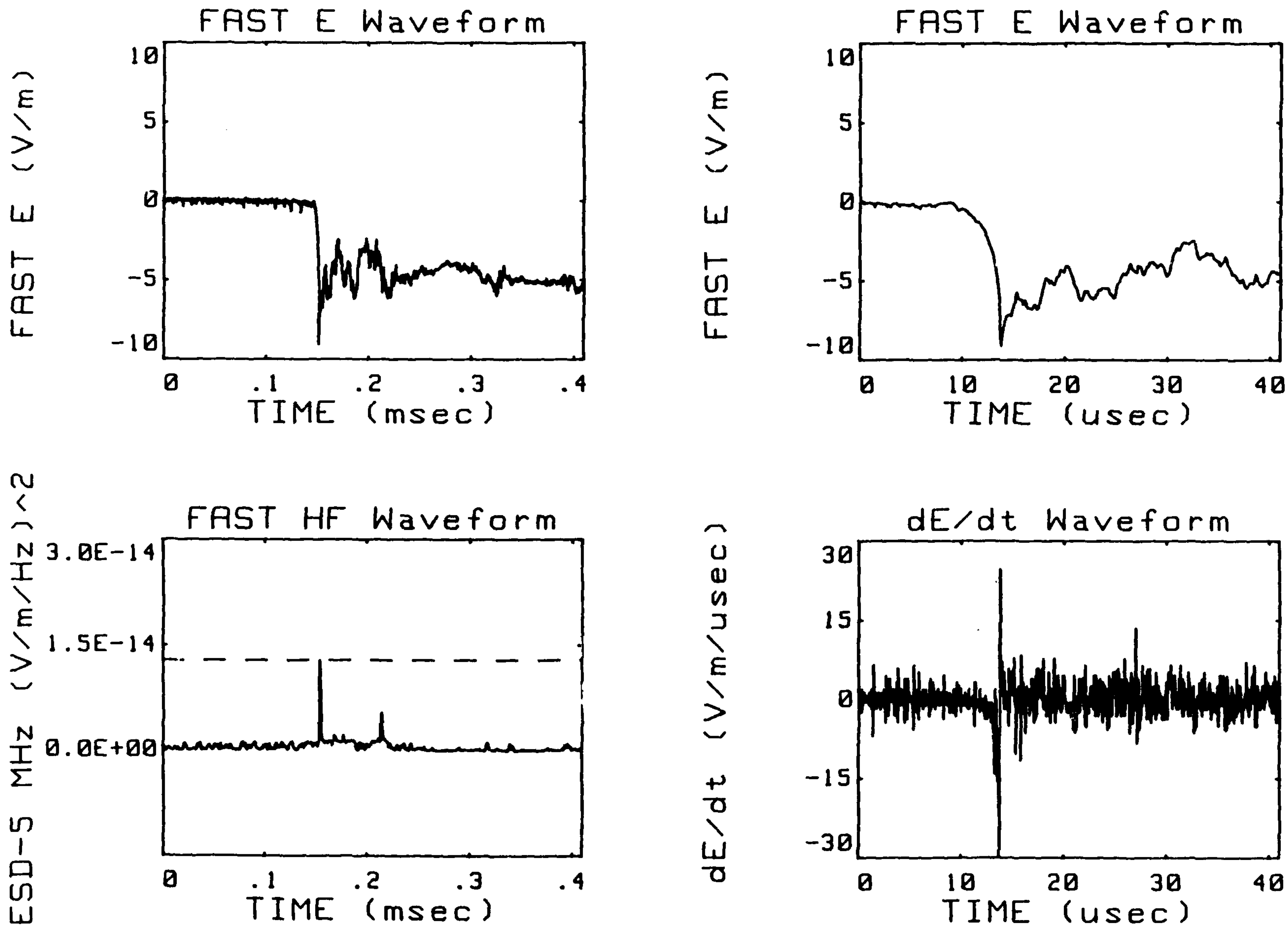
226174528.924 1985 DS Subs RS (15.3 Km)

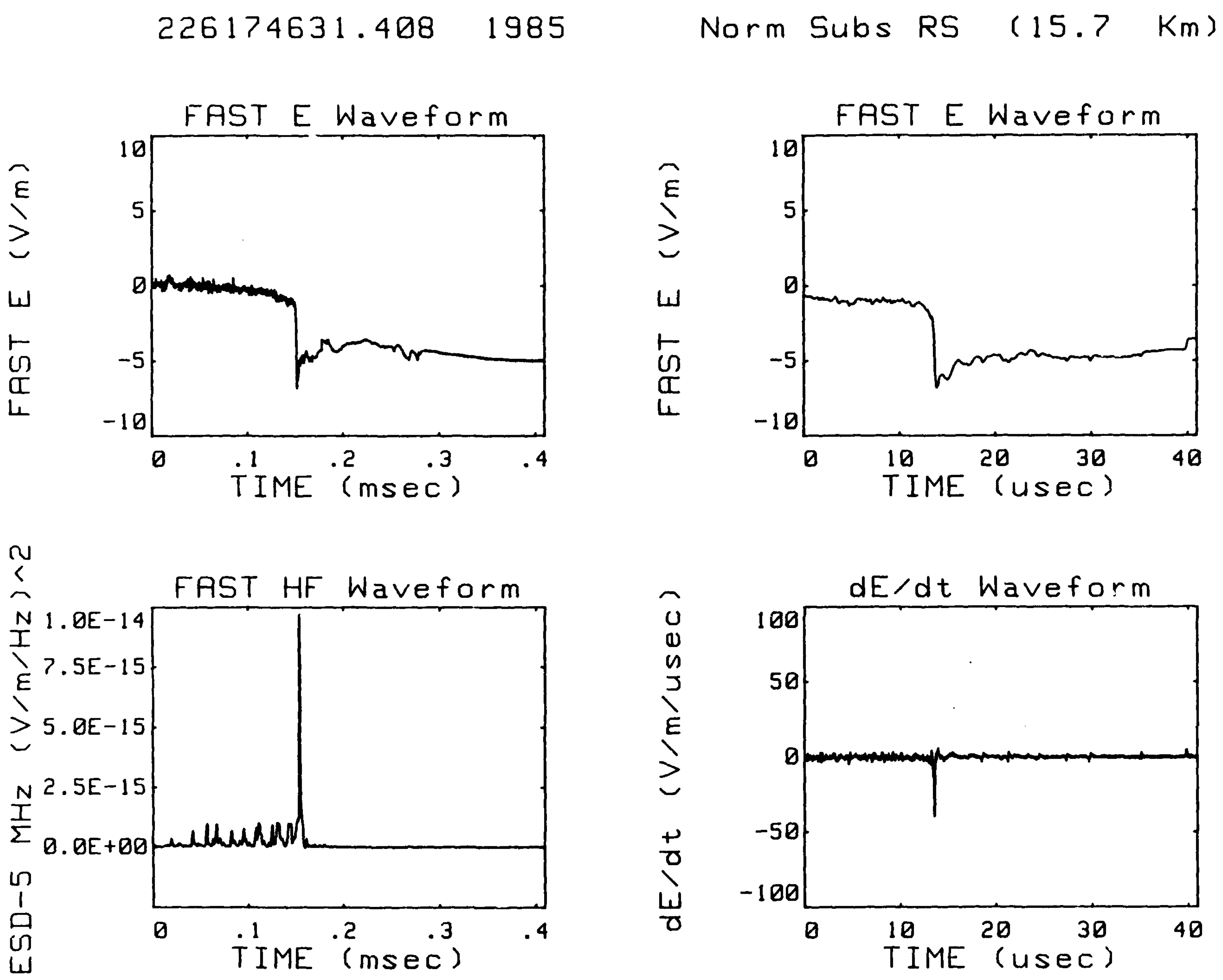


17:45:28.094 14 Aug 1985 (15.3 Km)



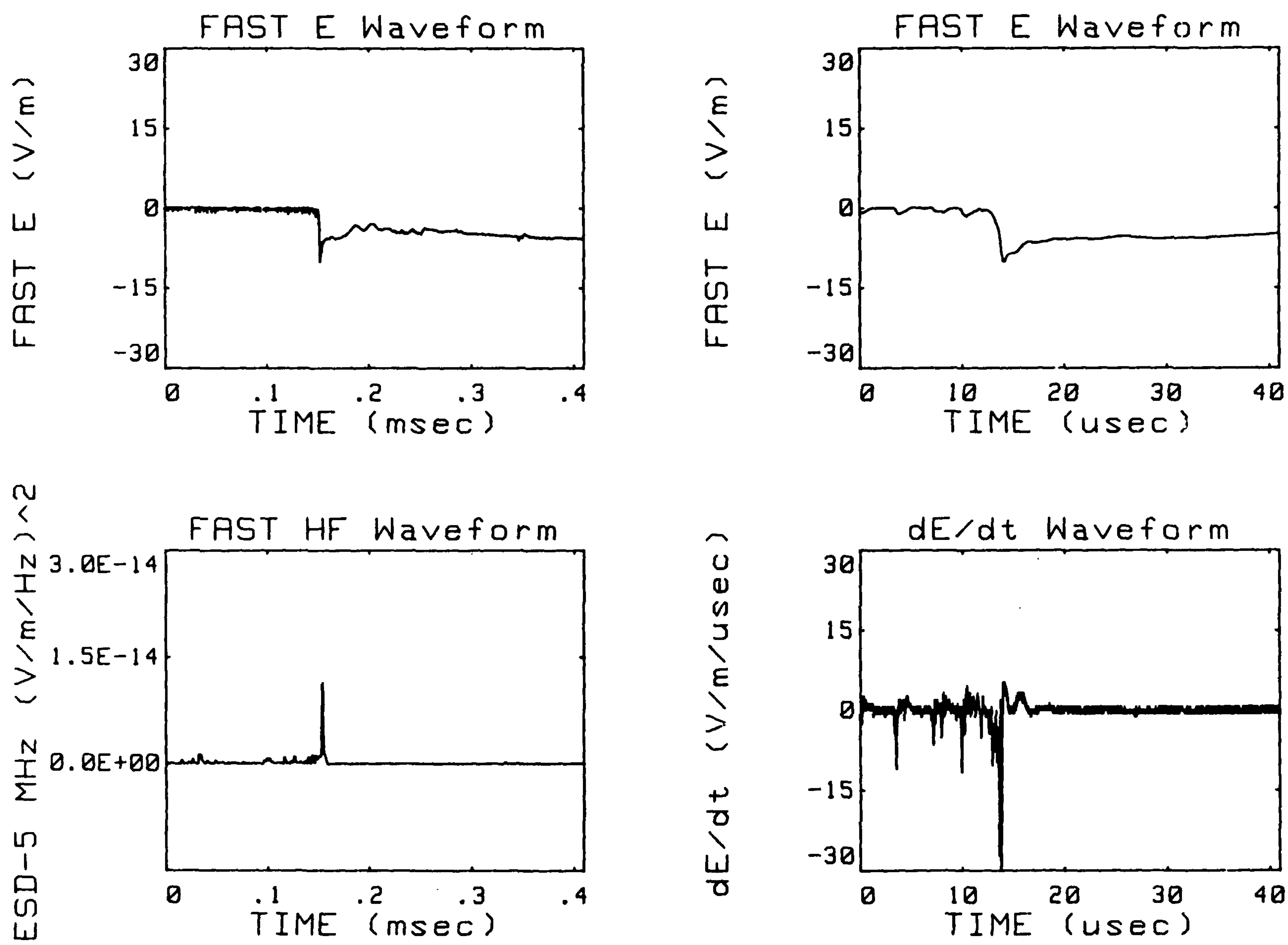
226174631.310 1985 1st RS (15.7 Km)

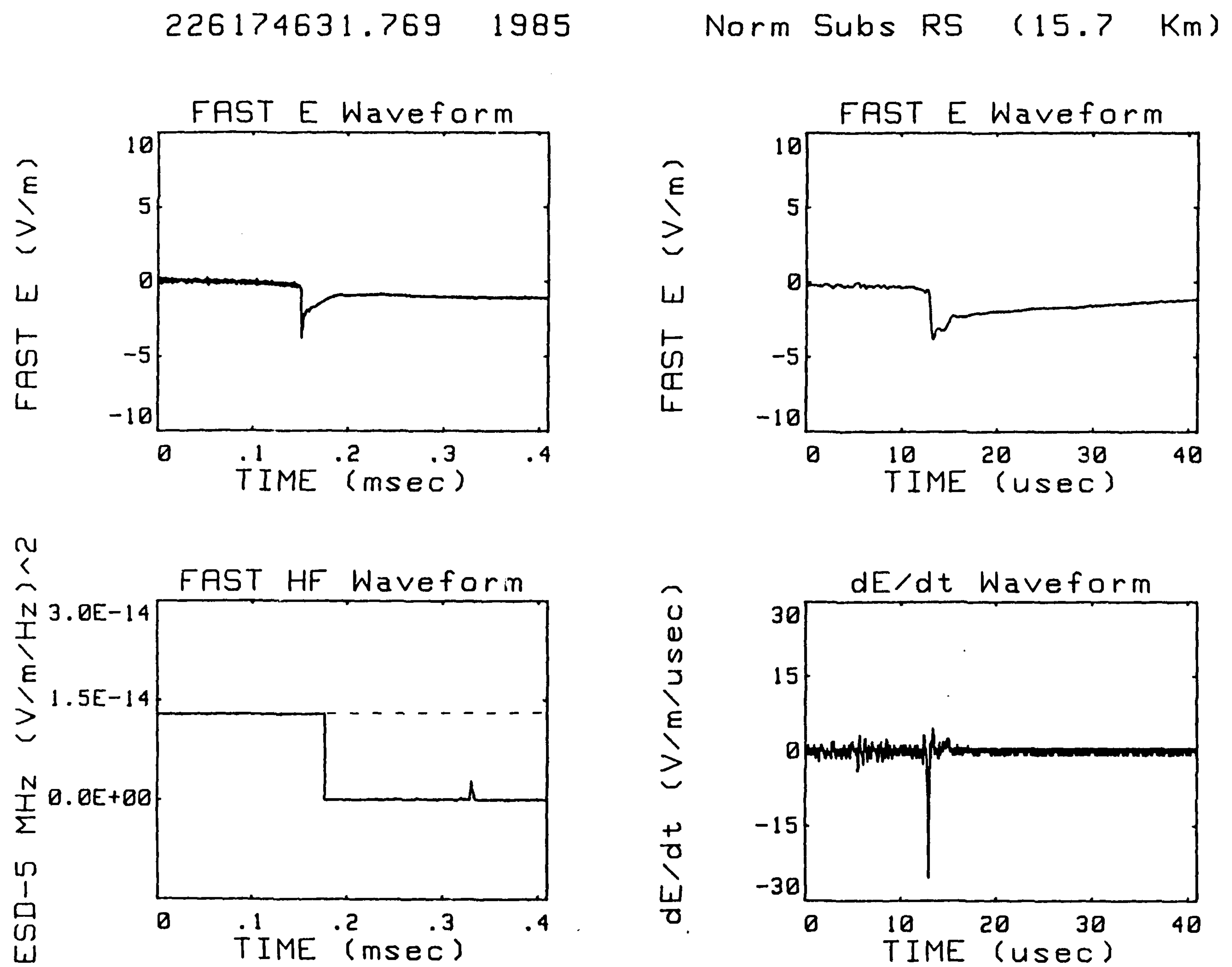




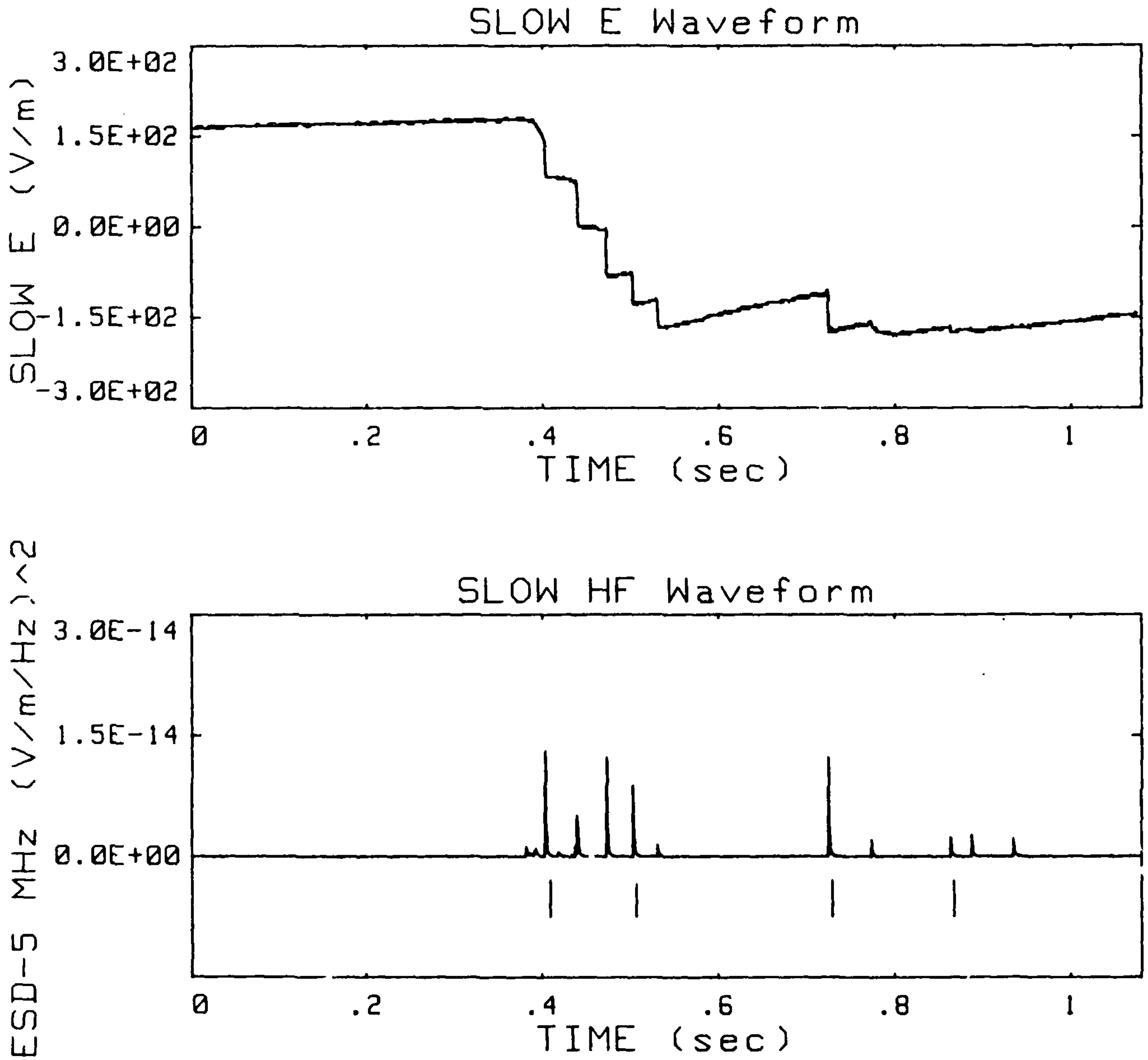
226174631.408 1985
Norm Subs RS (15.7 Km)
FAST E Waveform
FAST E (V/m)
10
5
0
-5
-10
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
10
5
0
-5
-10
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
1.0E-14
7.5E-15
5.0E-15
2.5E-15
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
100
50
0
-50
-100
0
10
20
30
40
TIME (usec)

226174631.631 1985 DS Subs RS (15.7 Km)

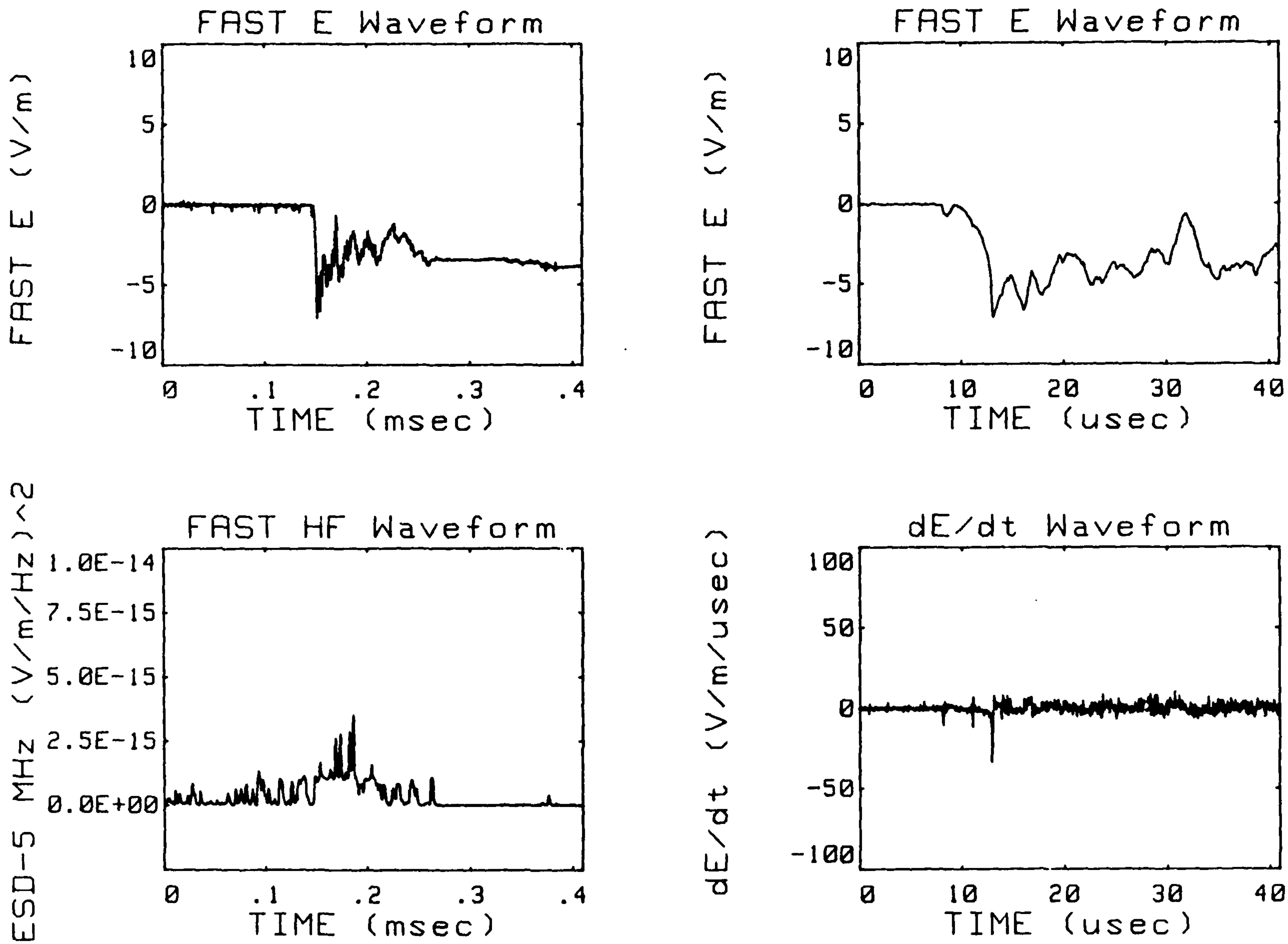



226174631.769 1985
Norm Subs RS (15.7 Km)
FAST E Waveform
FAST E (V/m)
10
5
0
-5
-10
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
10
5
0
-5
-10
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
3.0E-14
1.5E-14
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
30
15
0
-15
-30
0
10
20
30
40
TIME (usec)

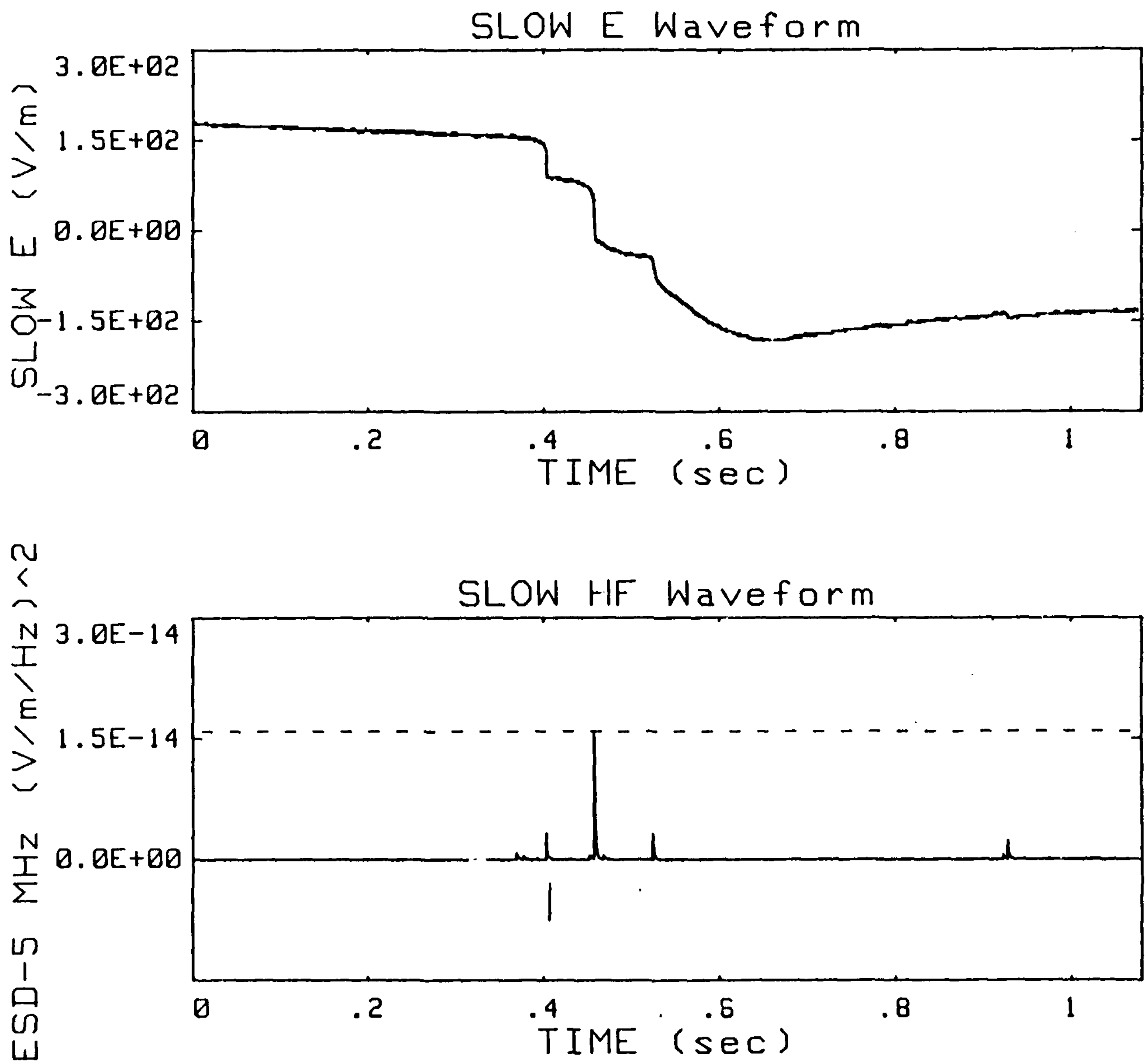
17:46:30.914 14 Aug 1985 (15.7 Km)



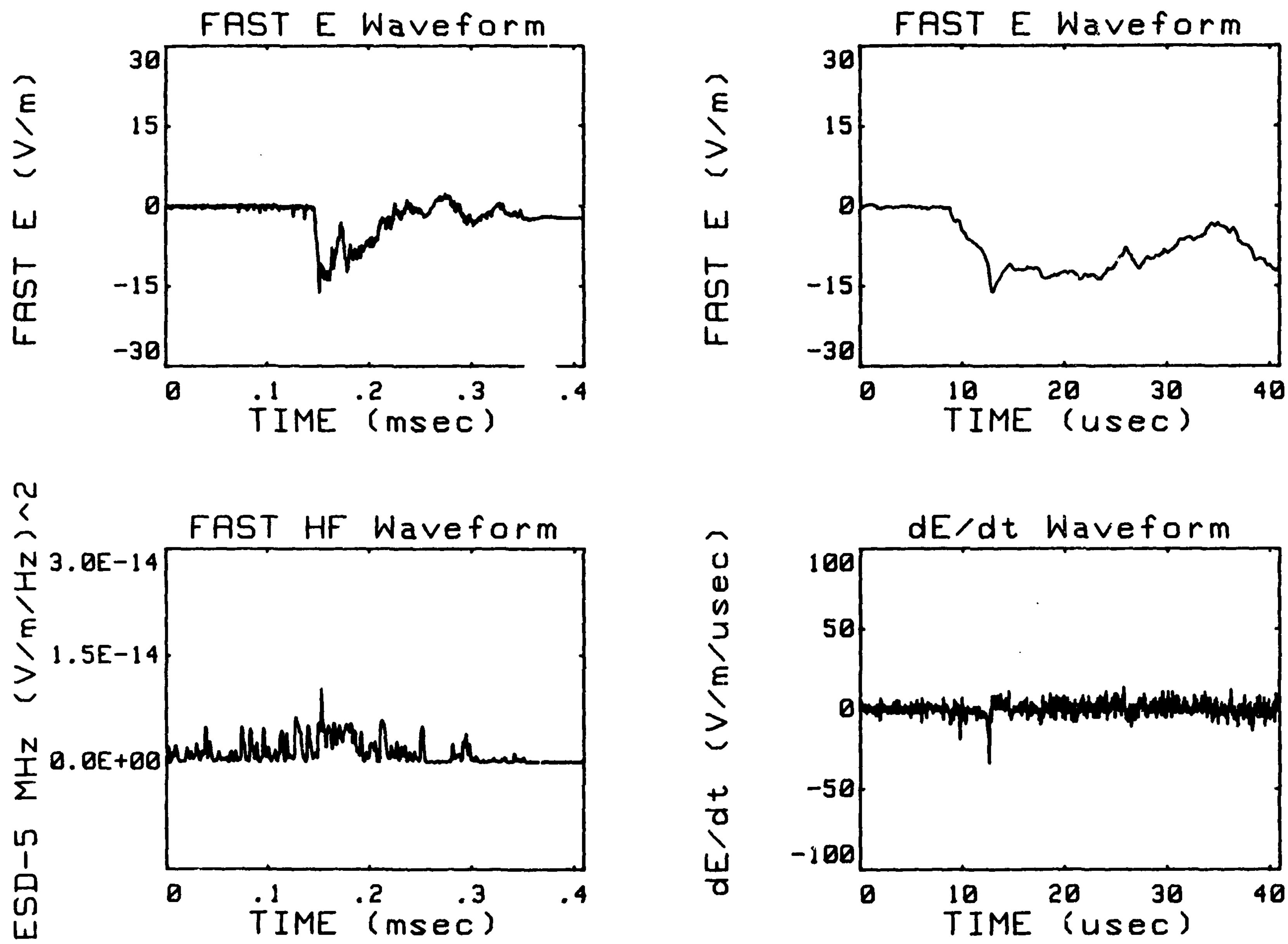
226174708.819 1985 1st RS (14.4 Km)



17:47:08.425   14 Aug 1985   (14.4   Km)

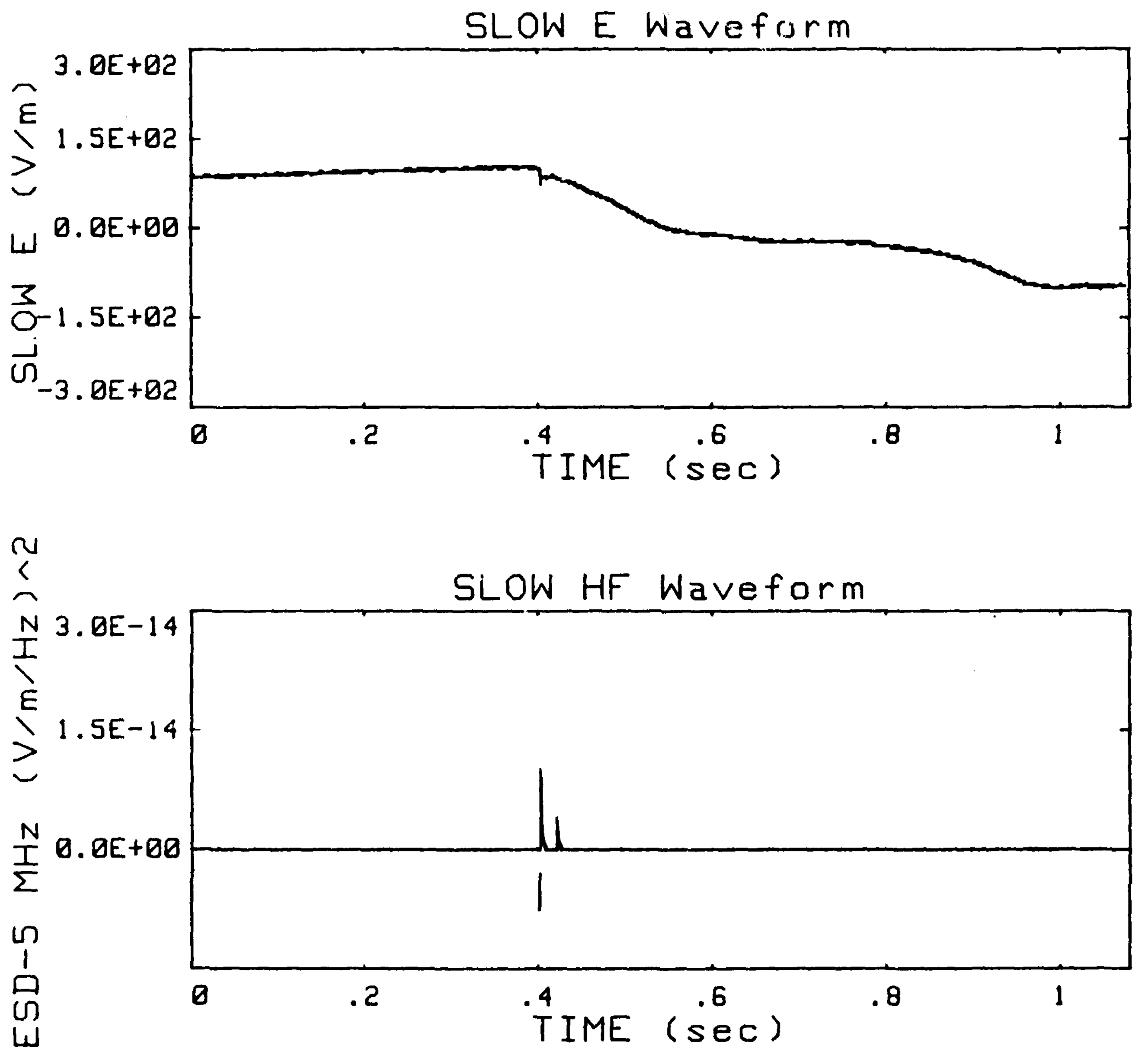


226174743.299 1985 1st RS (32.7 Km)

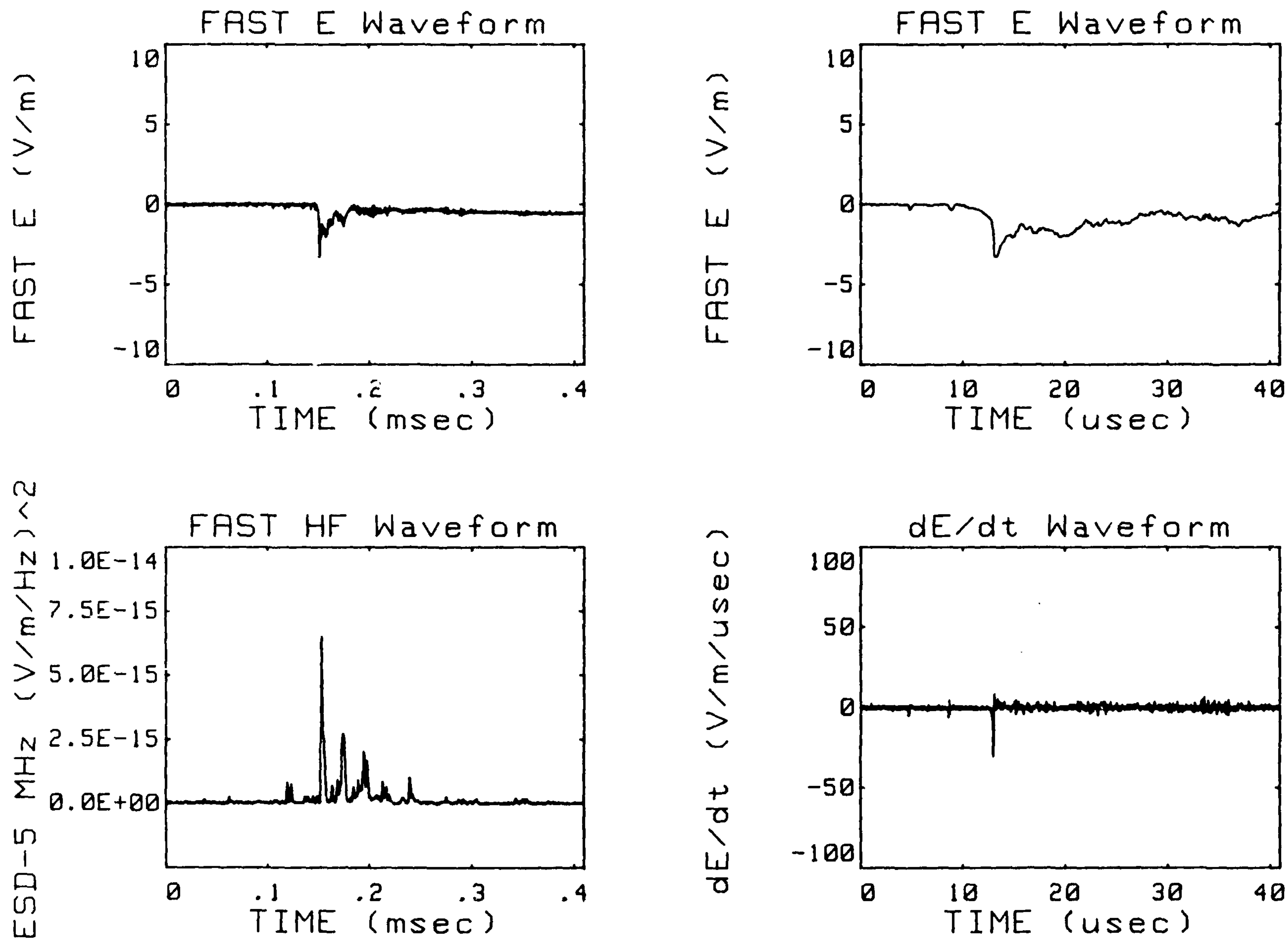


187

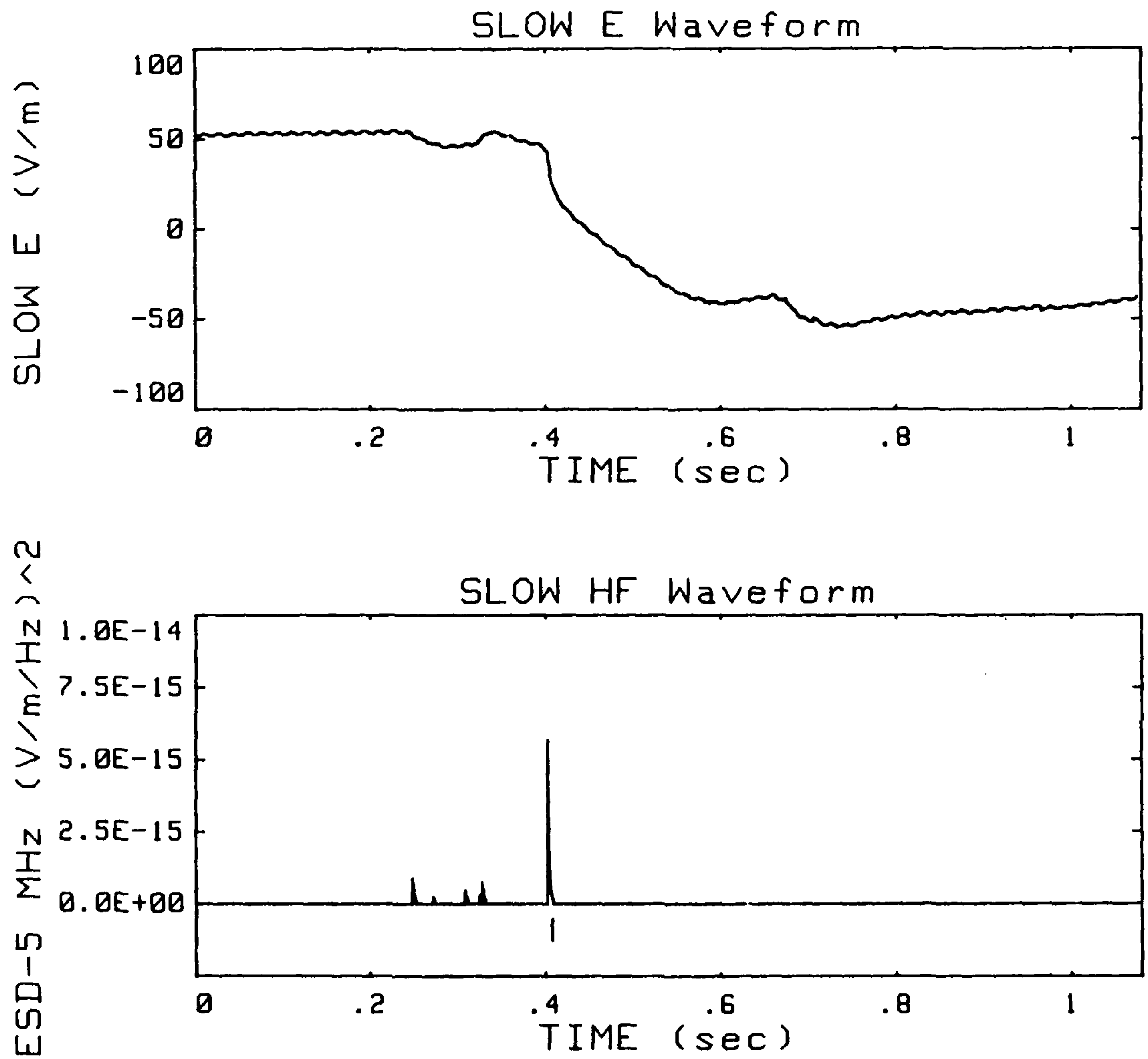
17:47:42.910 14 Aug 1985 (32.7 Km)



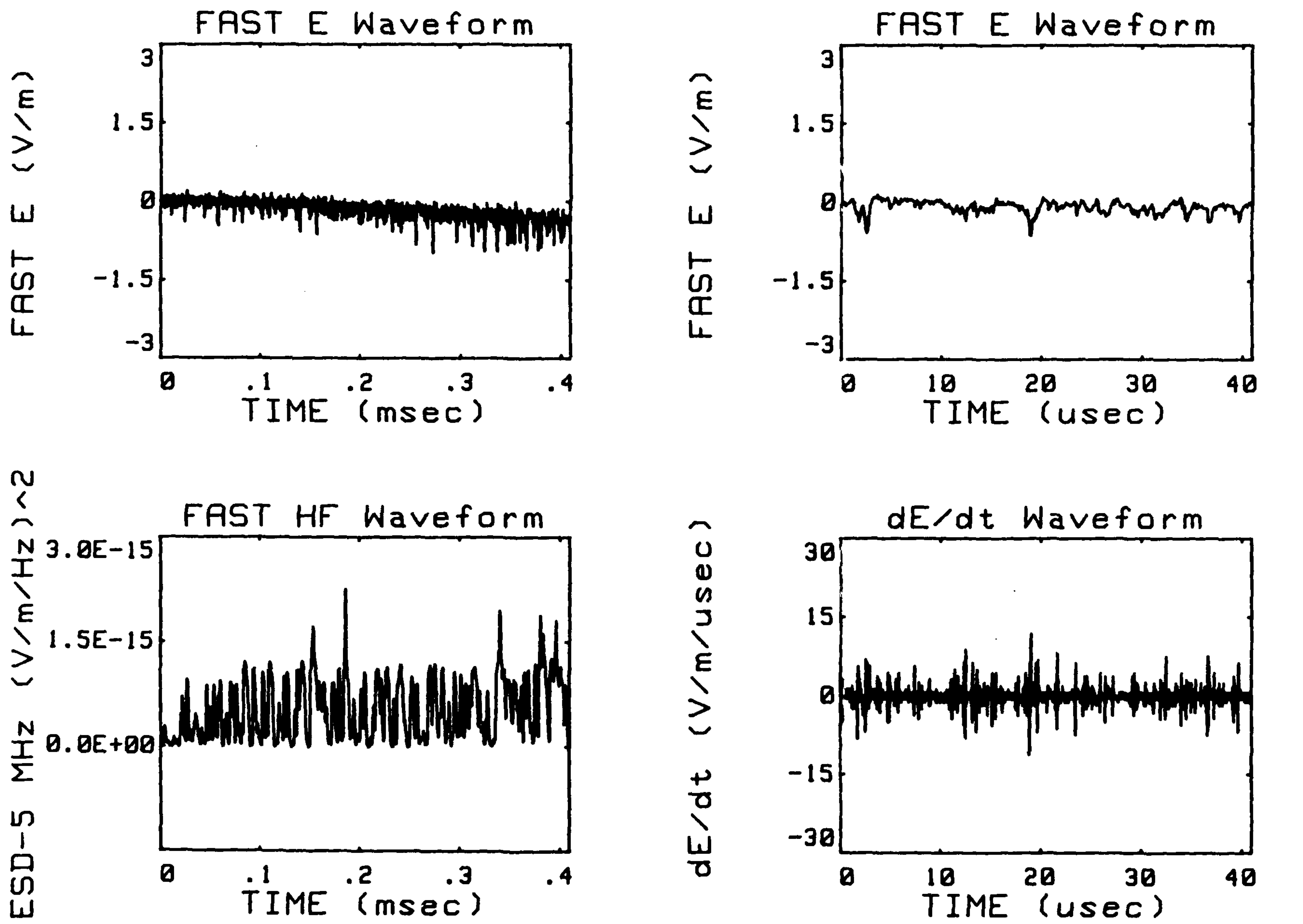
226174800.541   1985   1st RS (22.8 Km)



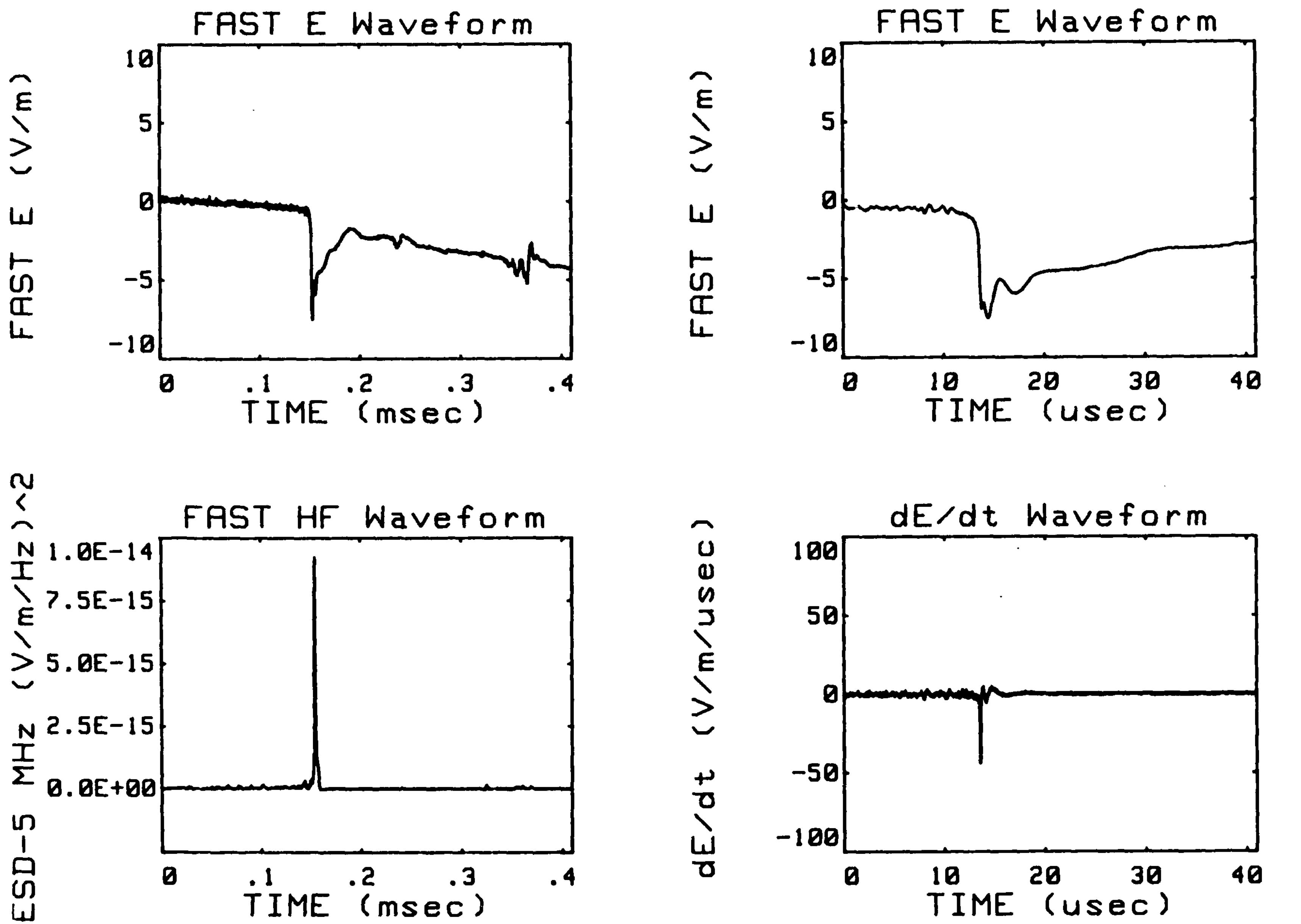
17:48:00.146   14 Aug 1985   (22.8 Km)



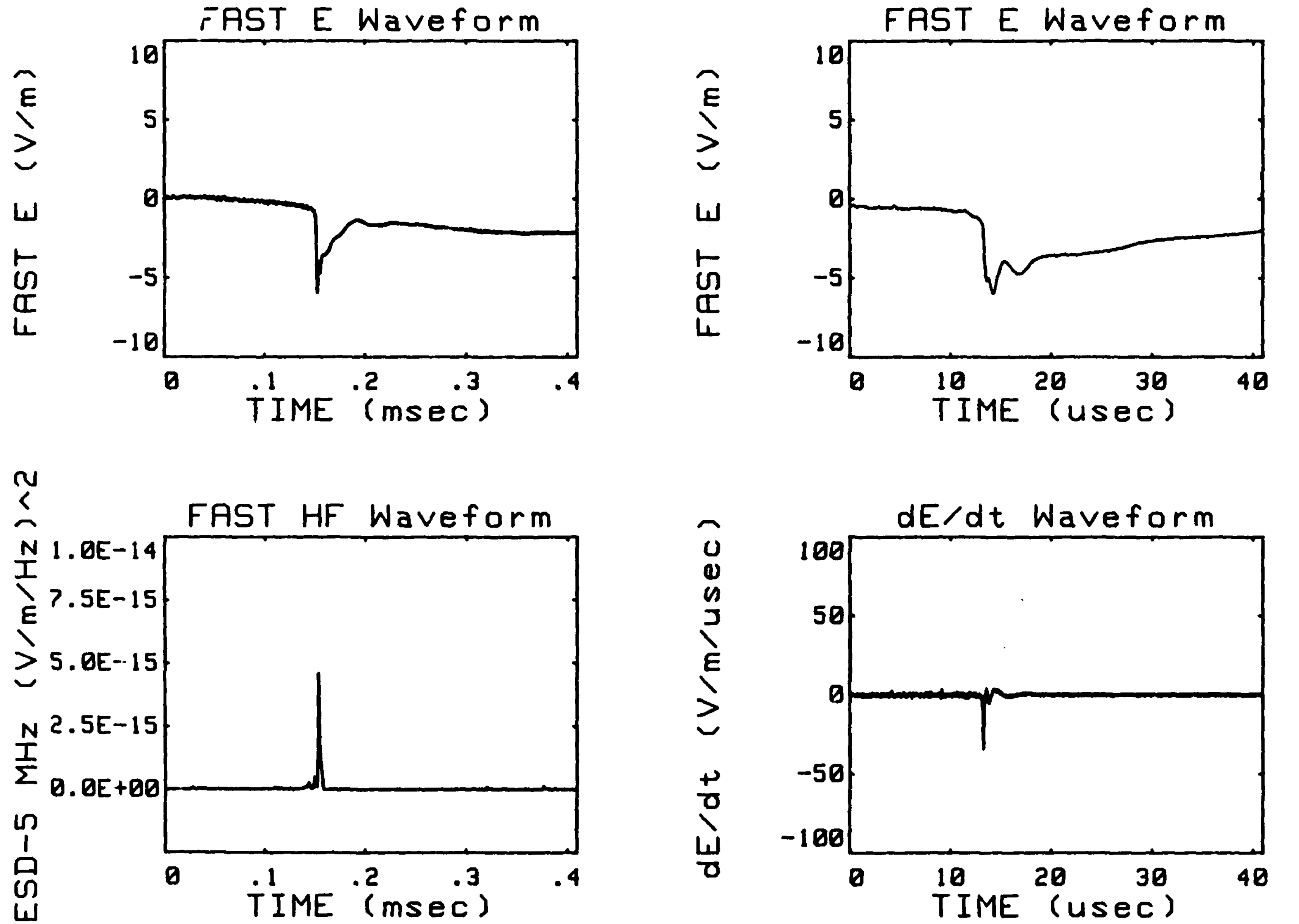
226174848.240 1985 Stepped Leader (15.1 Km)



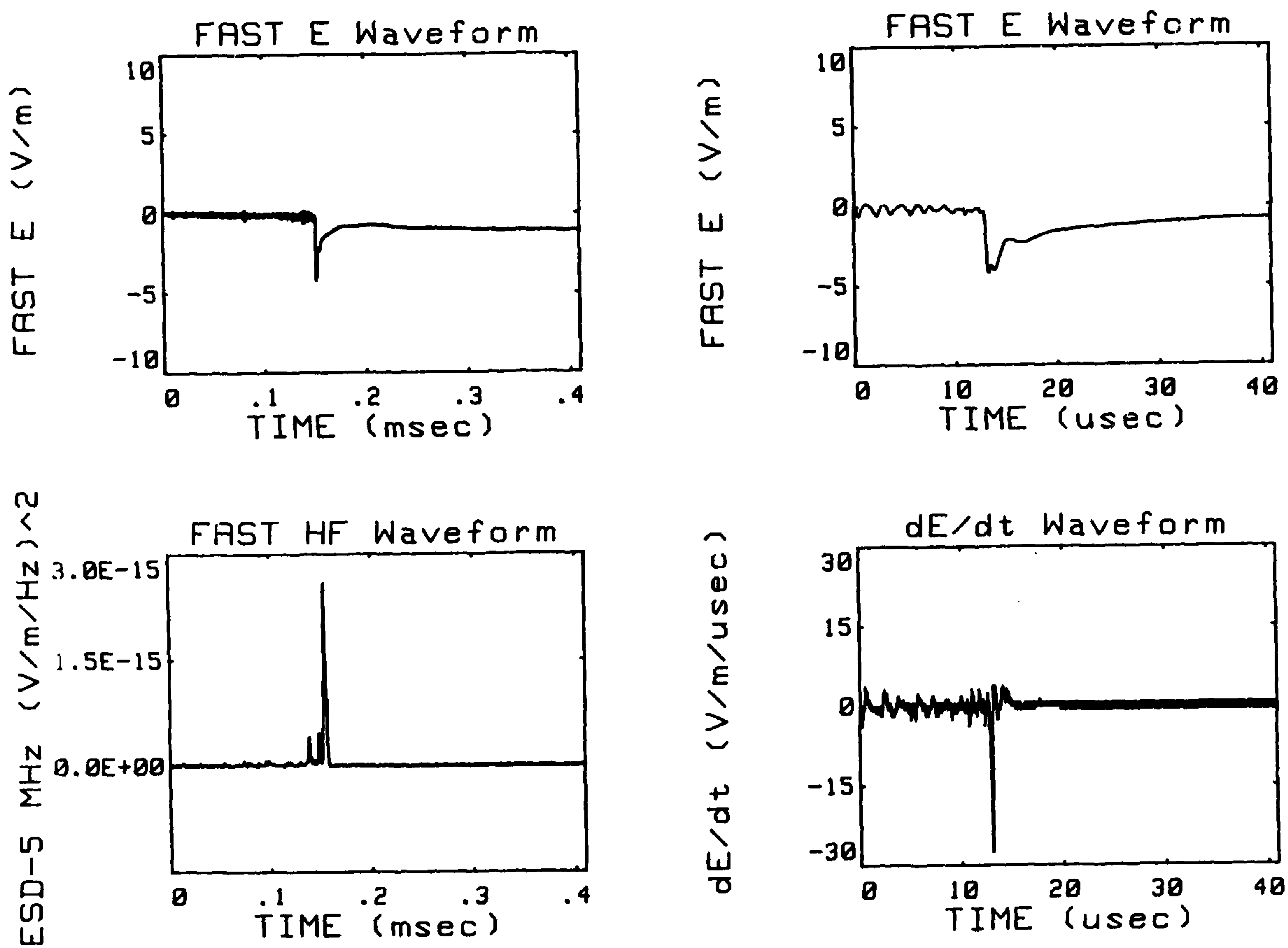
226174848.504 1985 Norm Subs RS (15.1 Km)



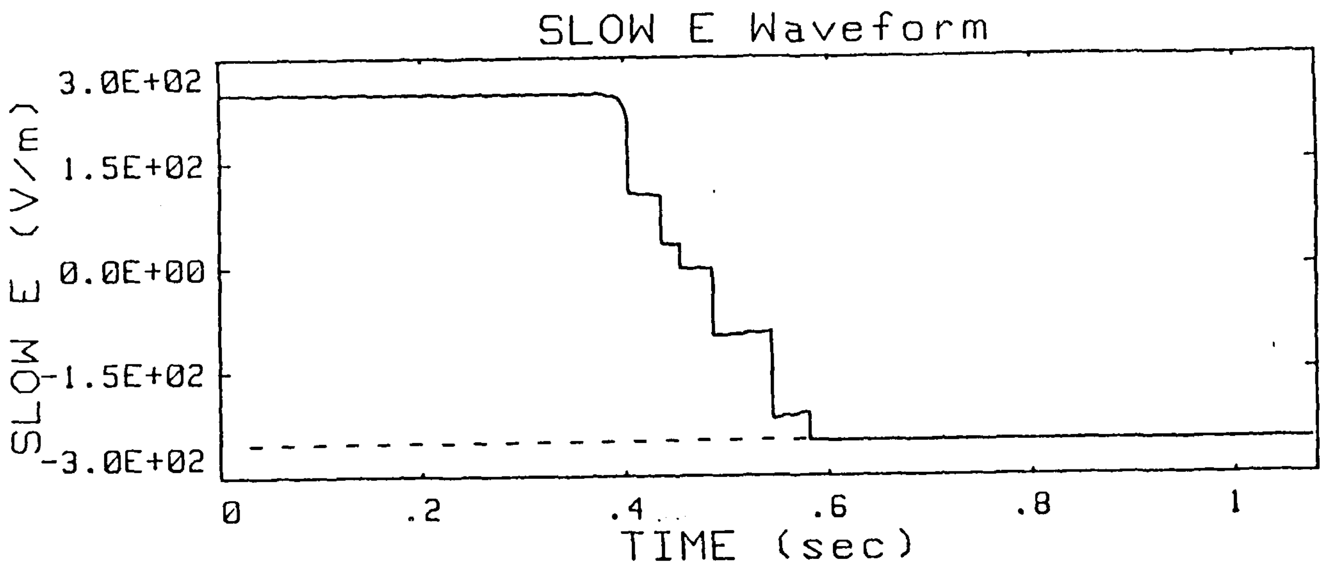
226174848.616 1985 Norm Subs RS (15.1 Km)

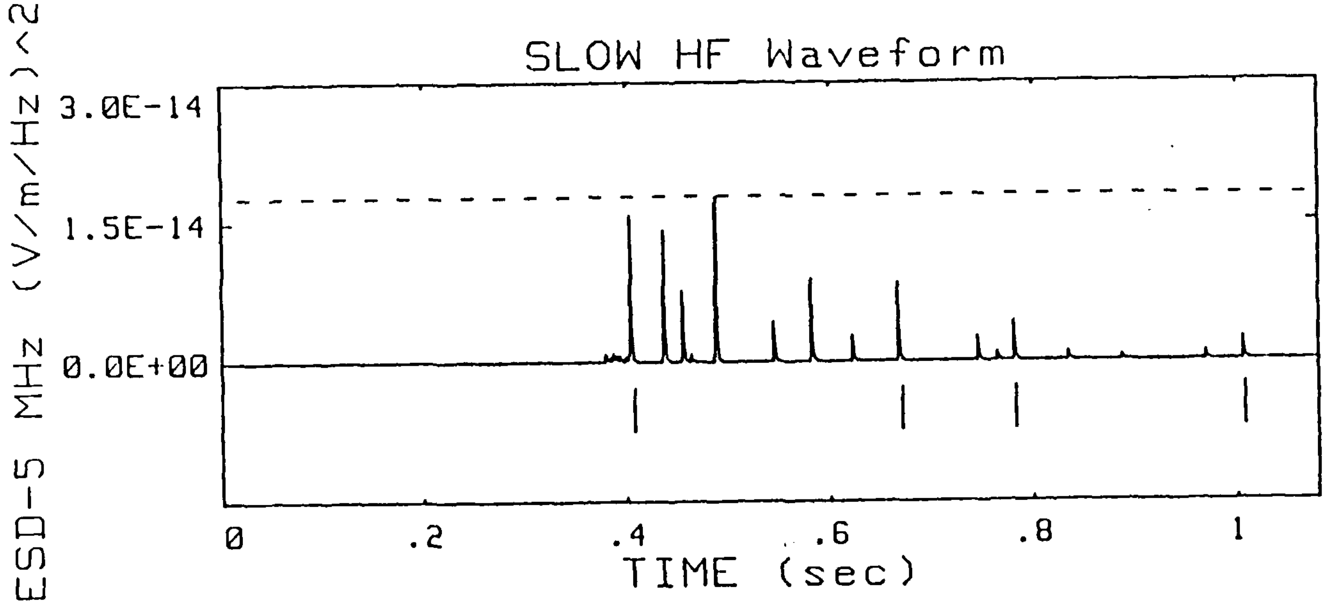


226174848.841 1985 DS Subs RS (15.1 Km)

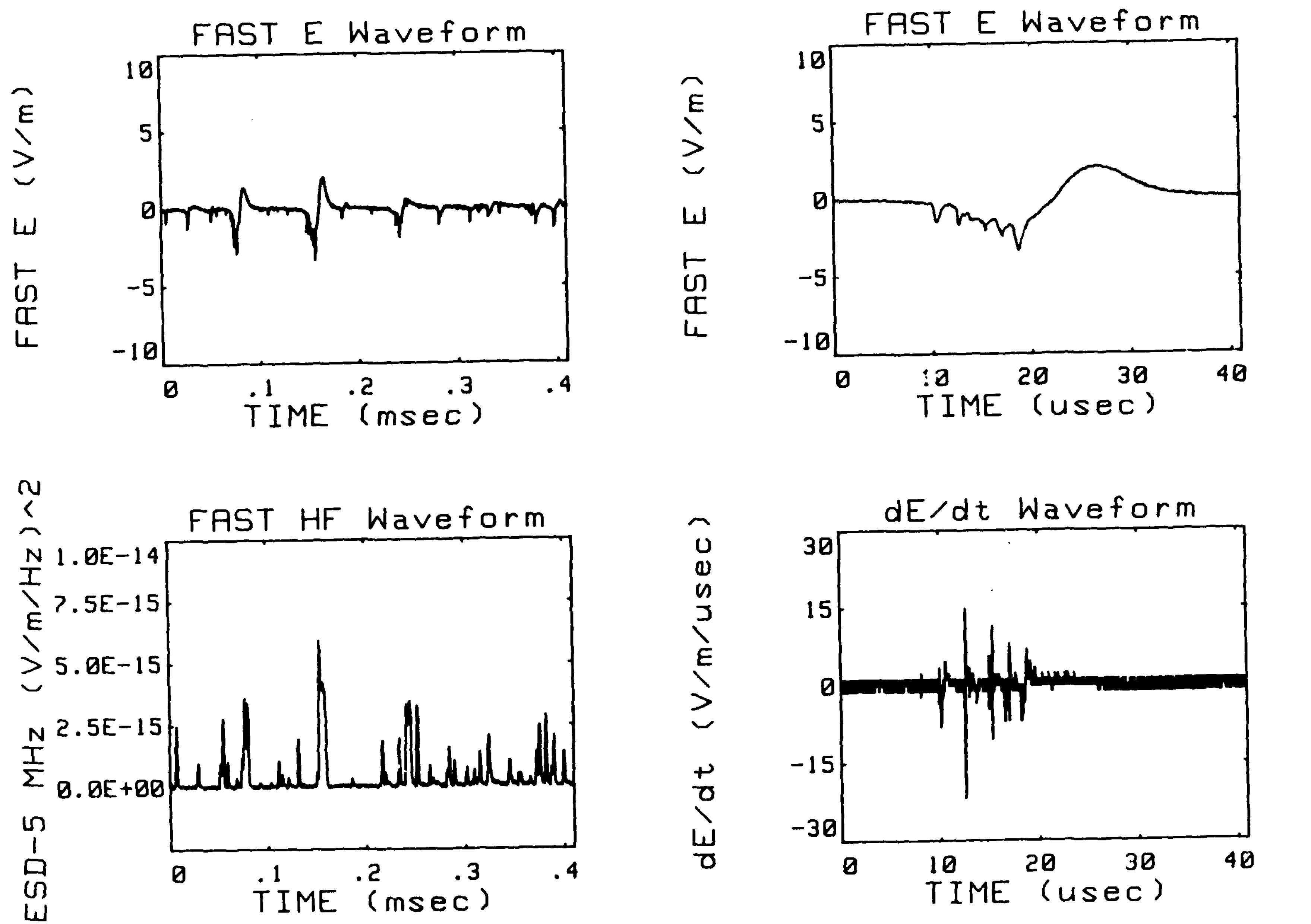


17:48:47.849 14 Aug 1985 (15.1 Km)

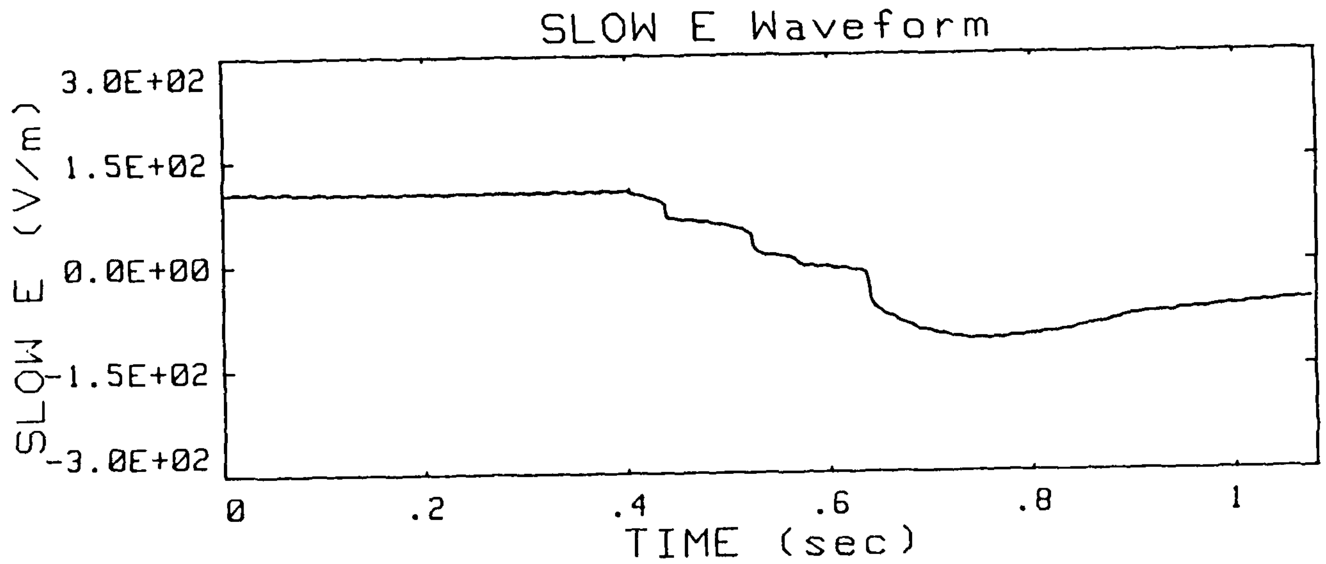


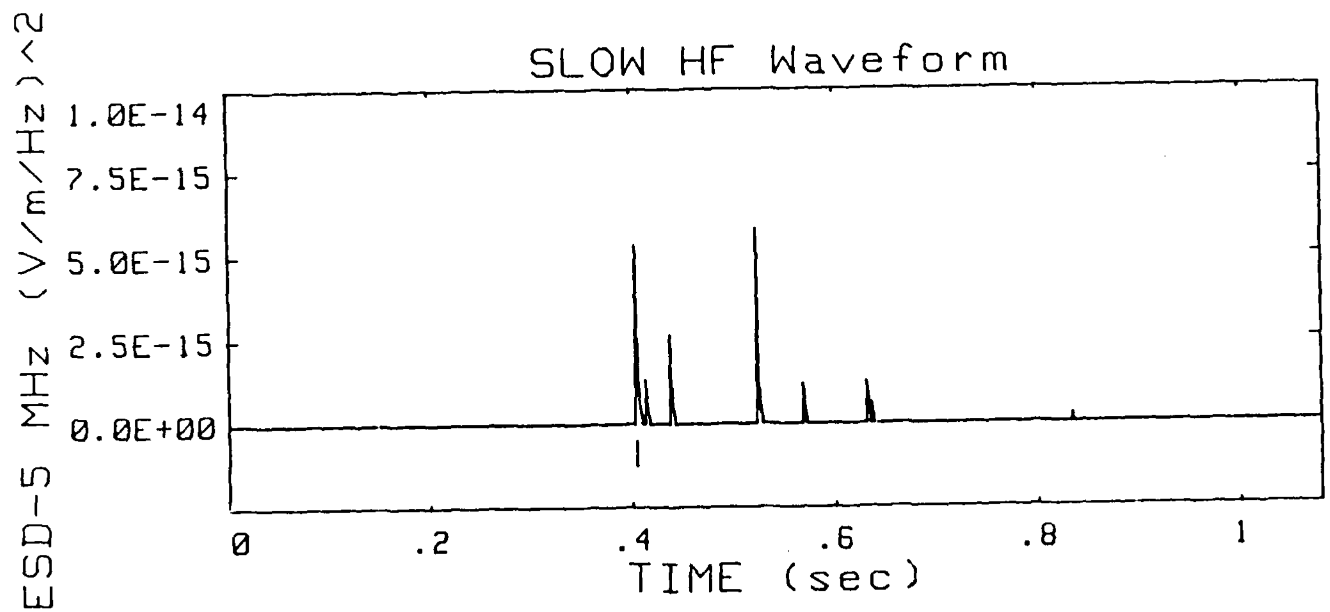


226174950.465 1985 Char Cloud Pulse (27.7 Km)

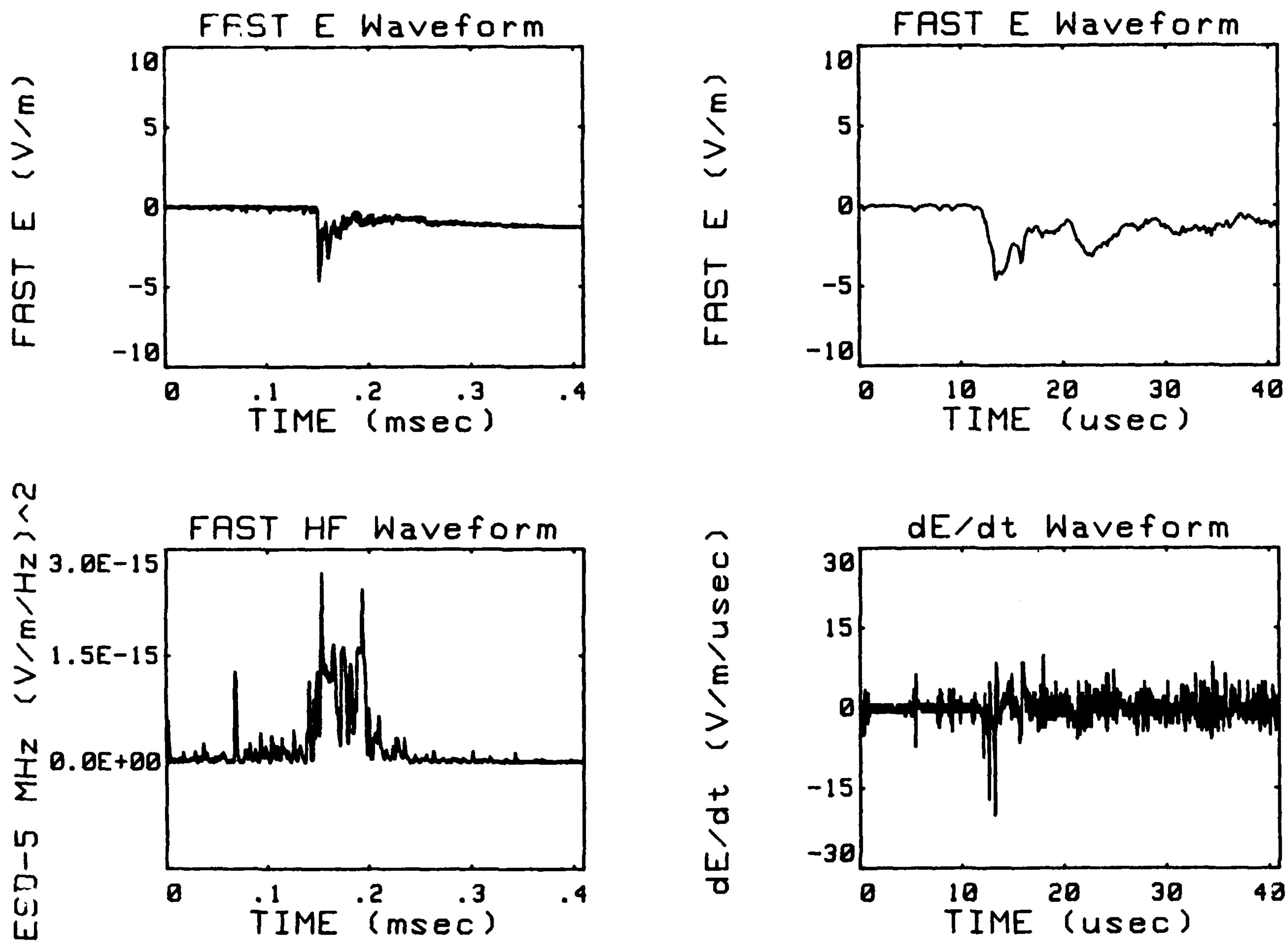


17:49:50.074 14 Aug 1985 (27.7 Km)

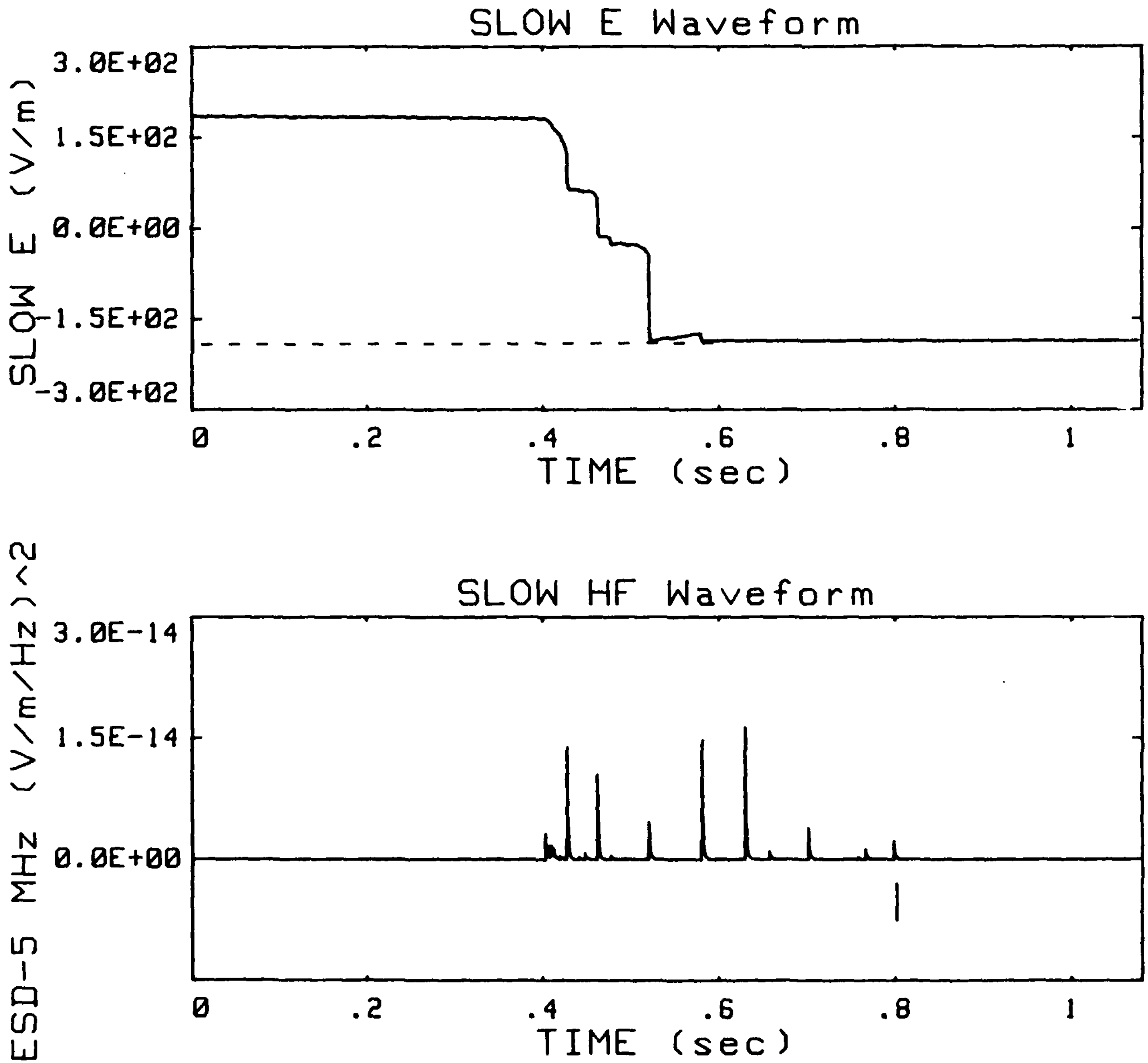




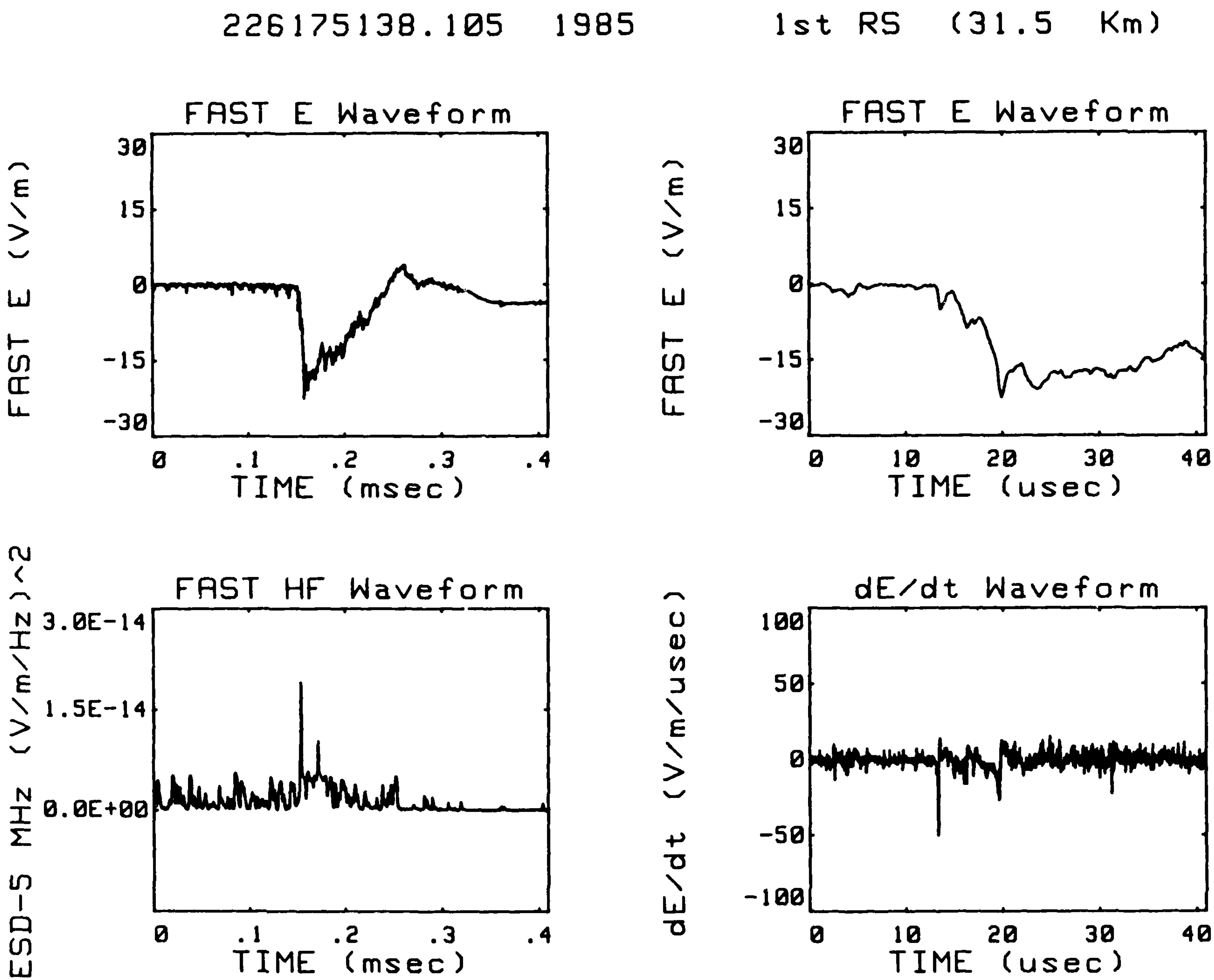
226175053.197   1985   1st RS   (17.2 Km)



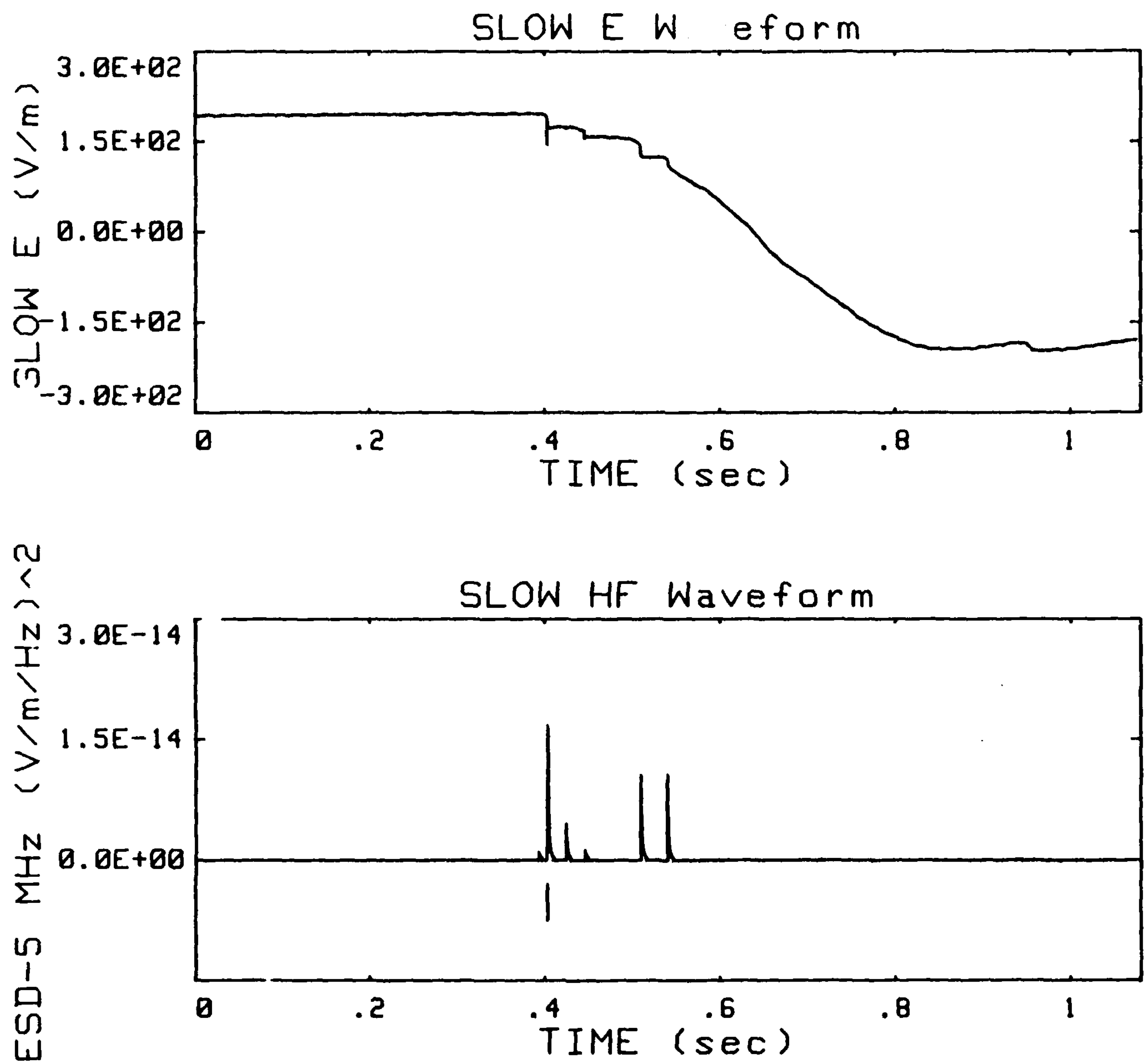
17:50:52.408 14 Aug 1985 (17.2 Km)



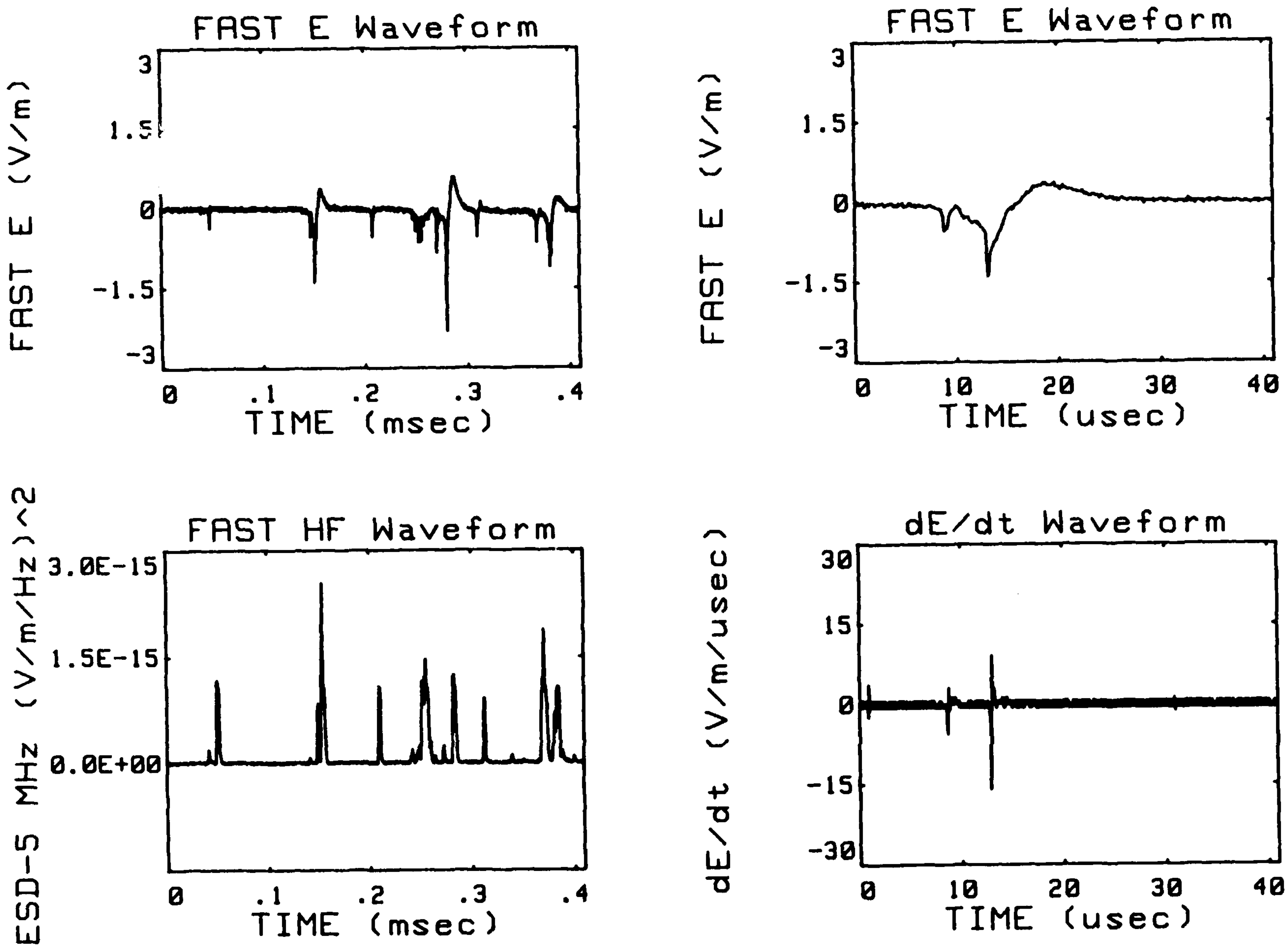
199


226175138.105 1985
1st RS (31.5 Km)
FAST E Waveform
FAST E (V/m)
30
15
0
-15
-30
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
30
15
0
-15
-30
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
3.0E-14
1.5E-14
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
100
50
0
-50
-100
0
10
20
30
40
TIME (usec)

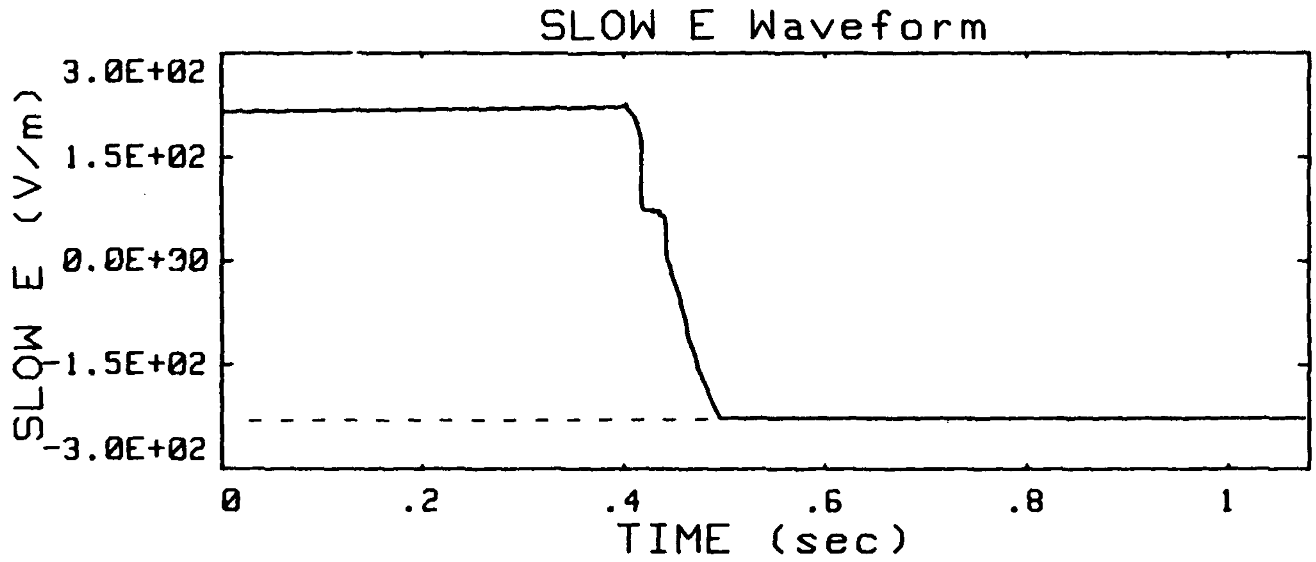
17:51:37.715 14 Aug 1985 (31.5 Km)

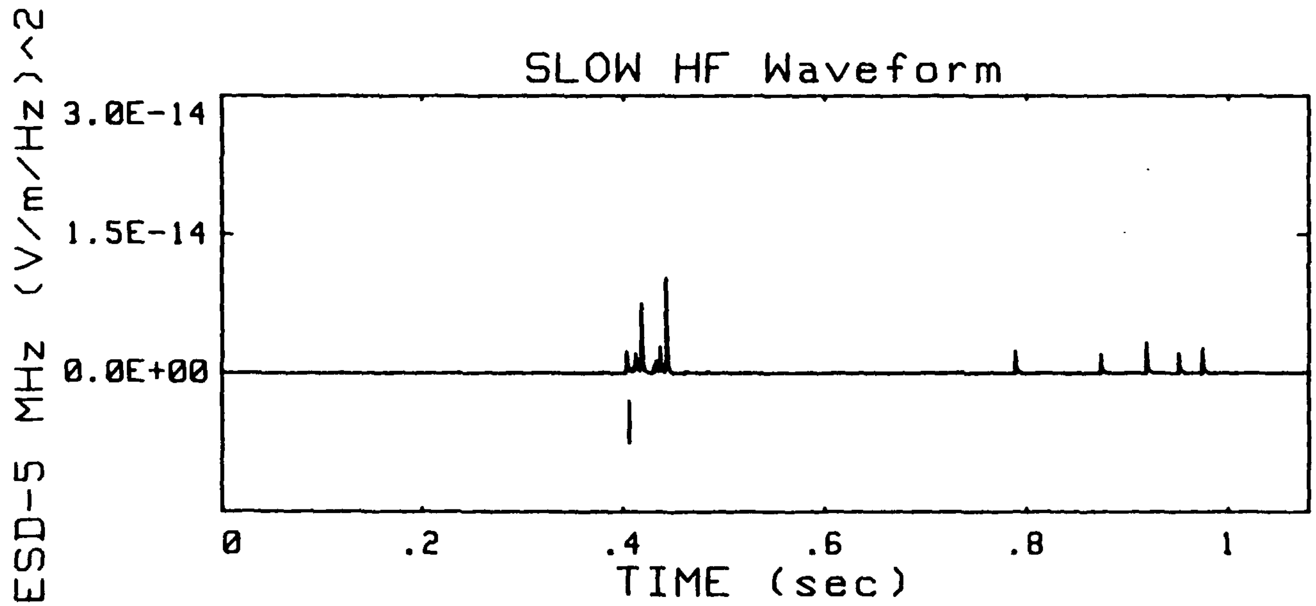


226175211.936 1985 Char Cloud Pulse (14.8 Km)

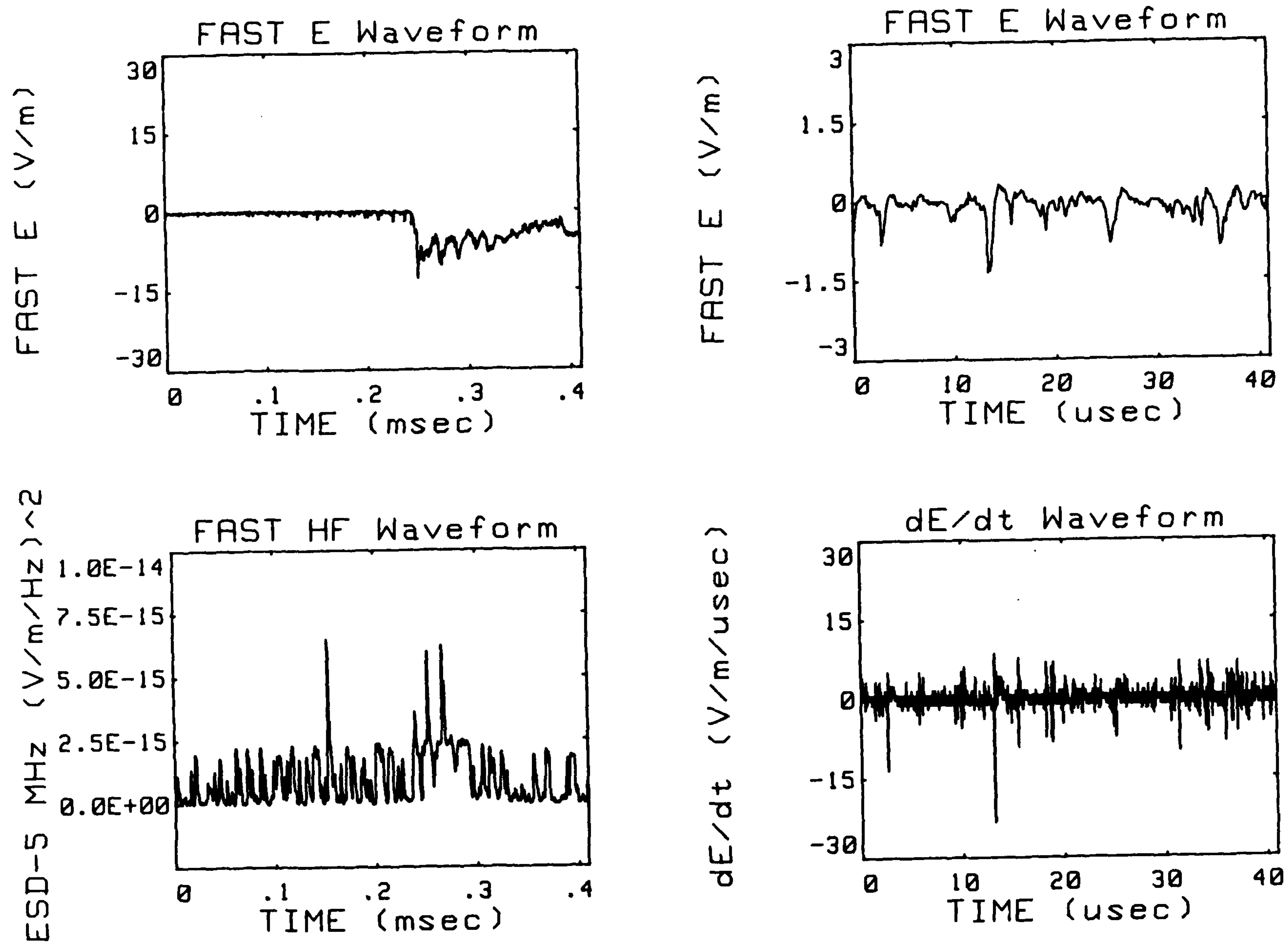


17:52:11.543 14 Aug 1985 (14.8 Km)



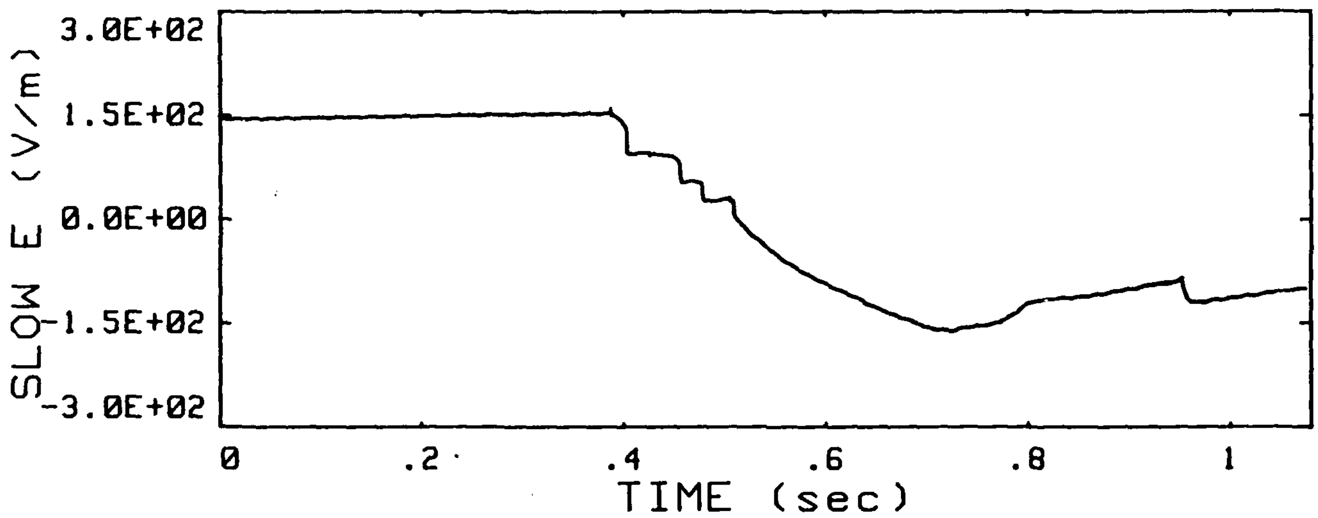


226175220.818 1985 Stepped Leader (21.4 Km)

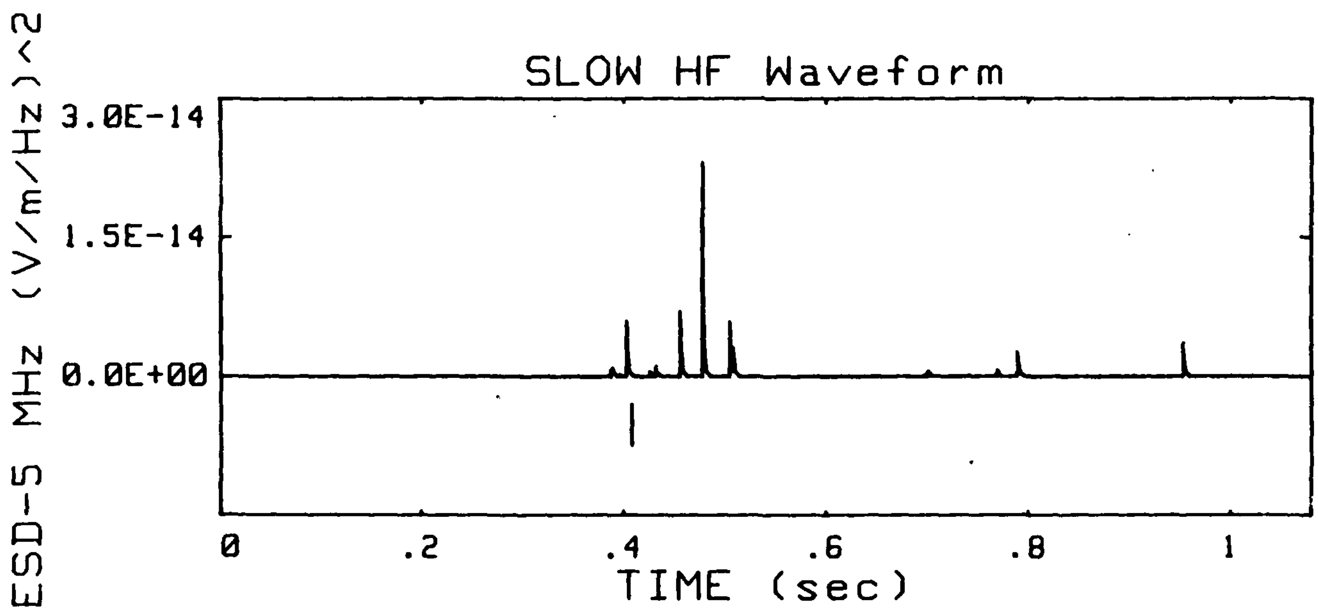


17:52:20.423 14 Aug 1985 (21.4 Km)

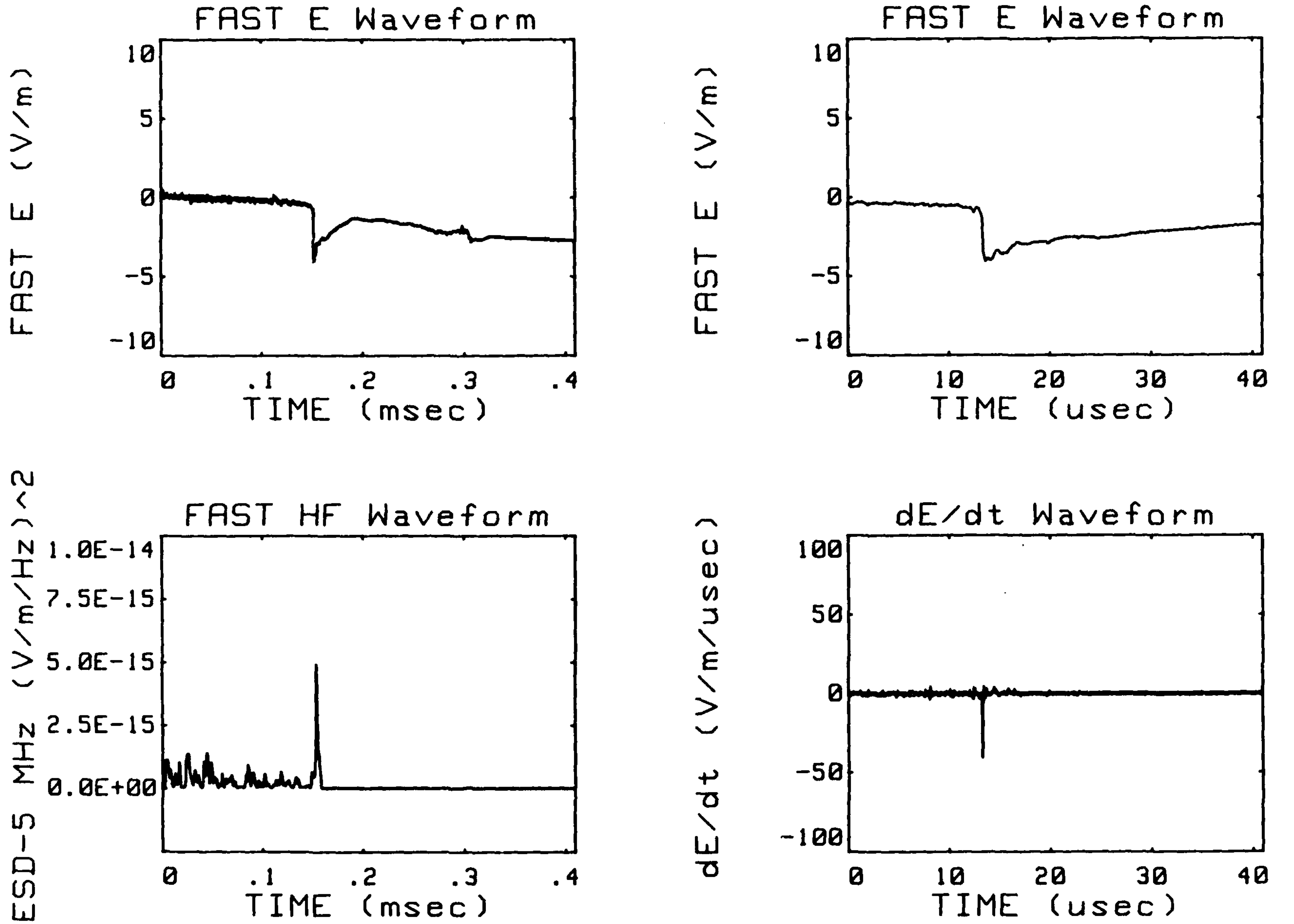
SLOW E Waveform



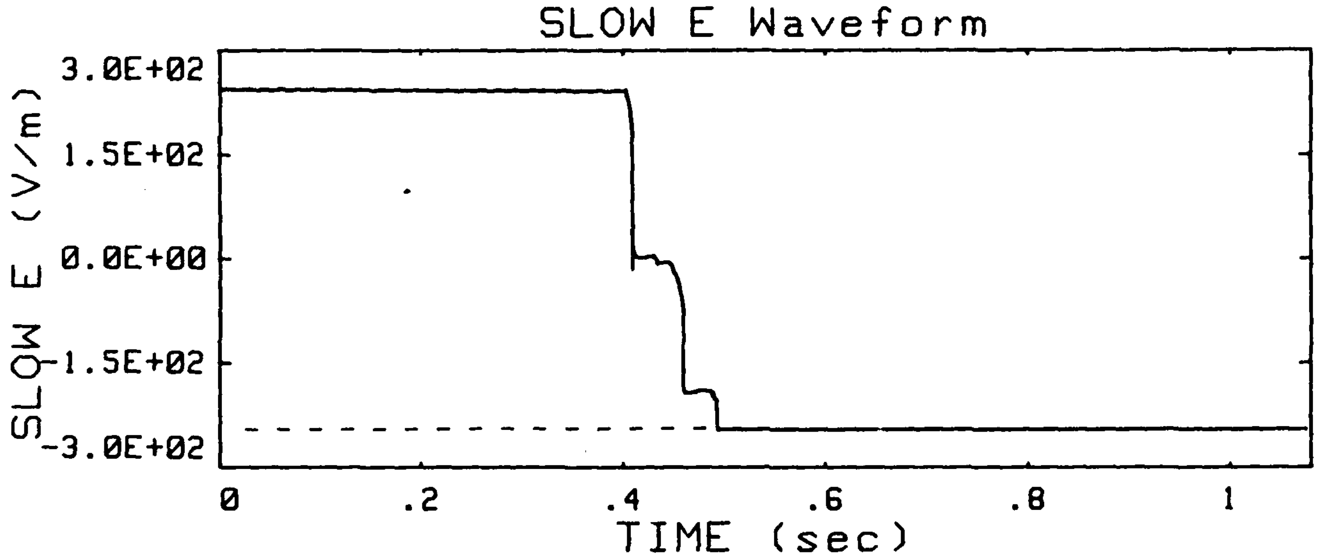
SLOW HF Waveform

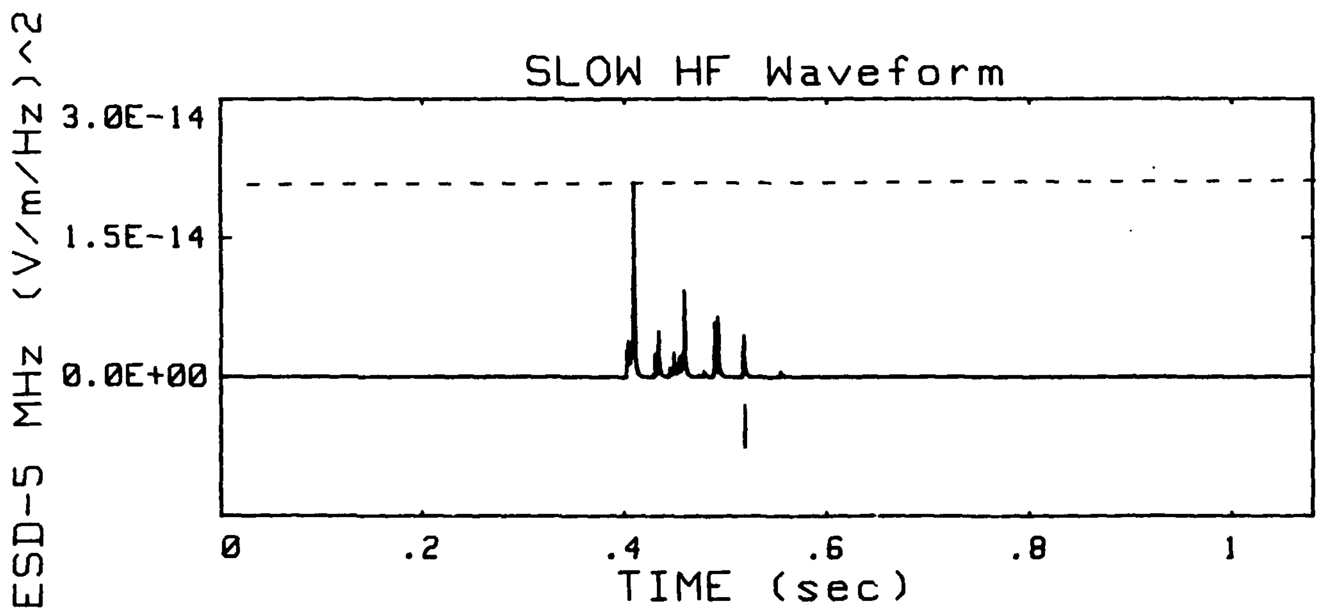


226175303.277 1985 Norm Subs RS (16.5 Km)

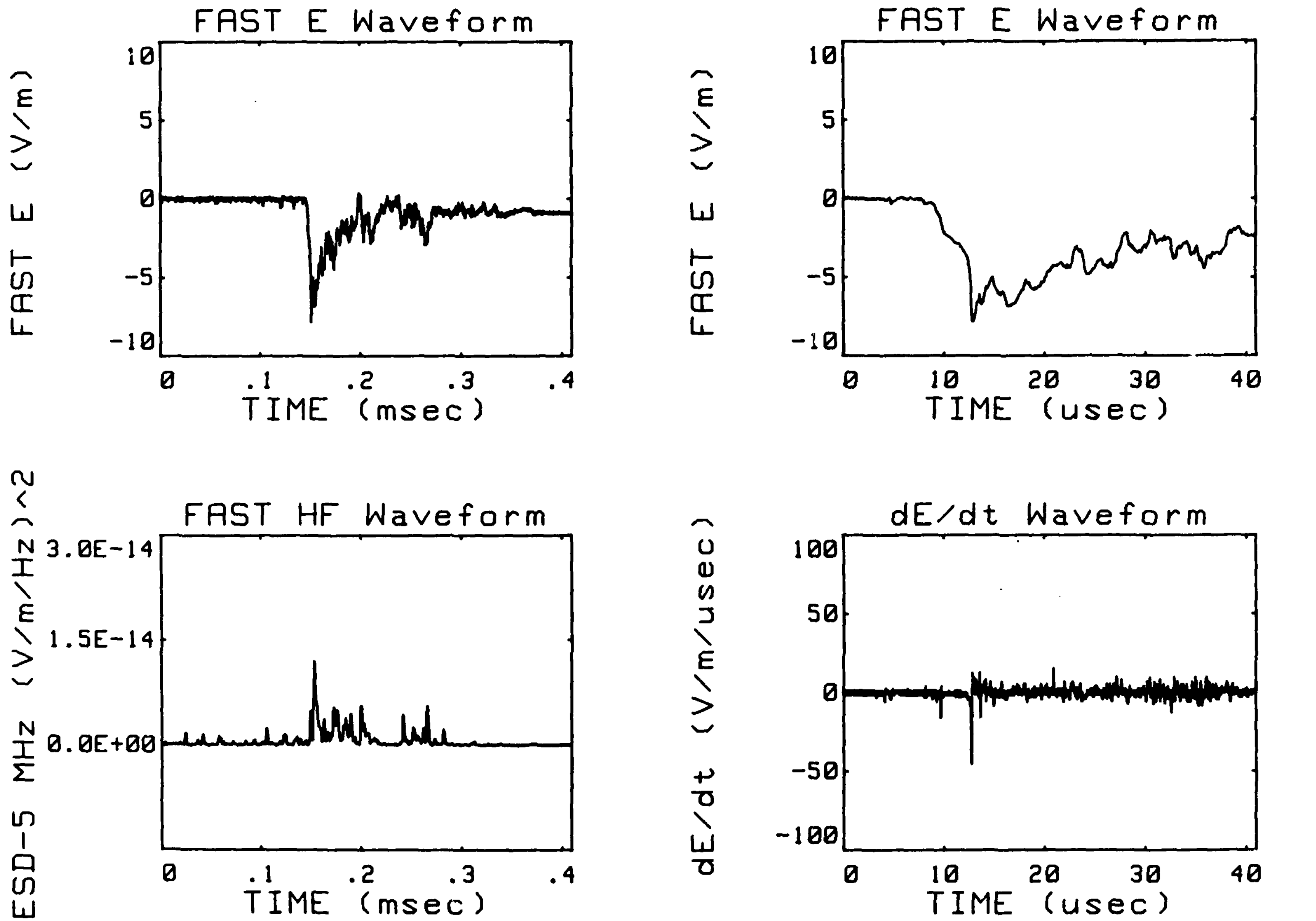


17:53:02.770 14 Aug 1985 (16.5 Km)

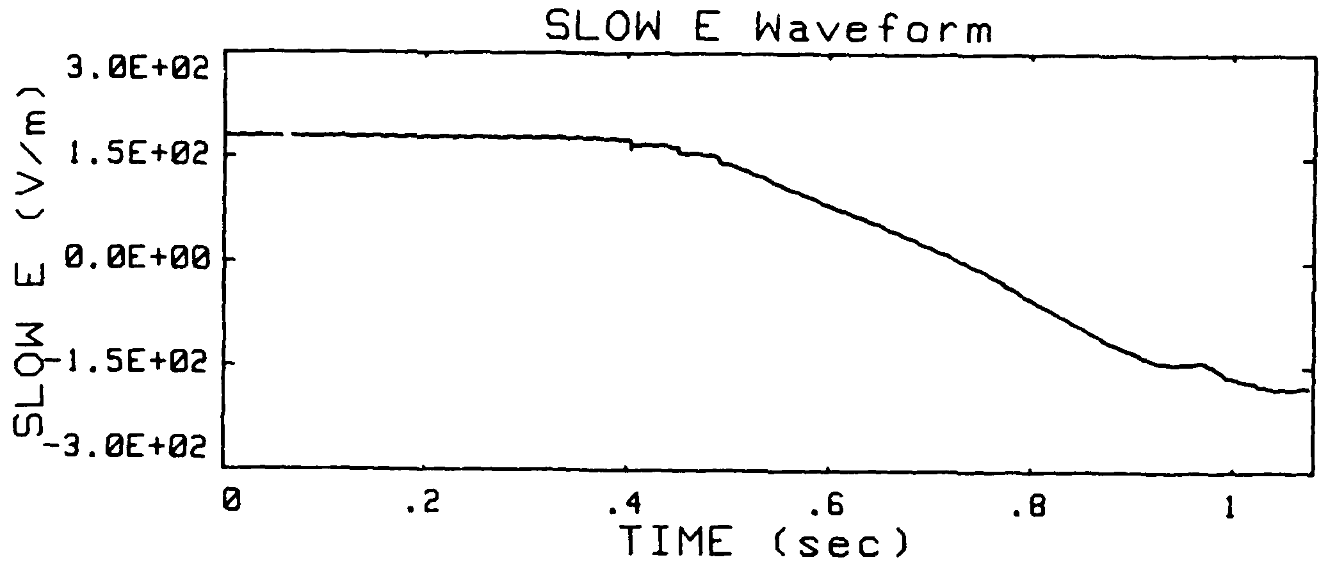


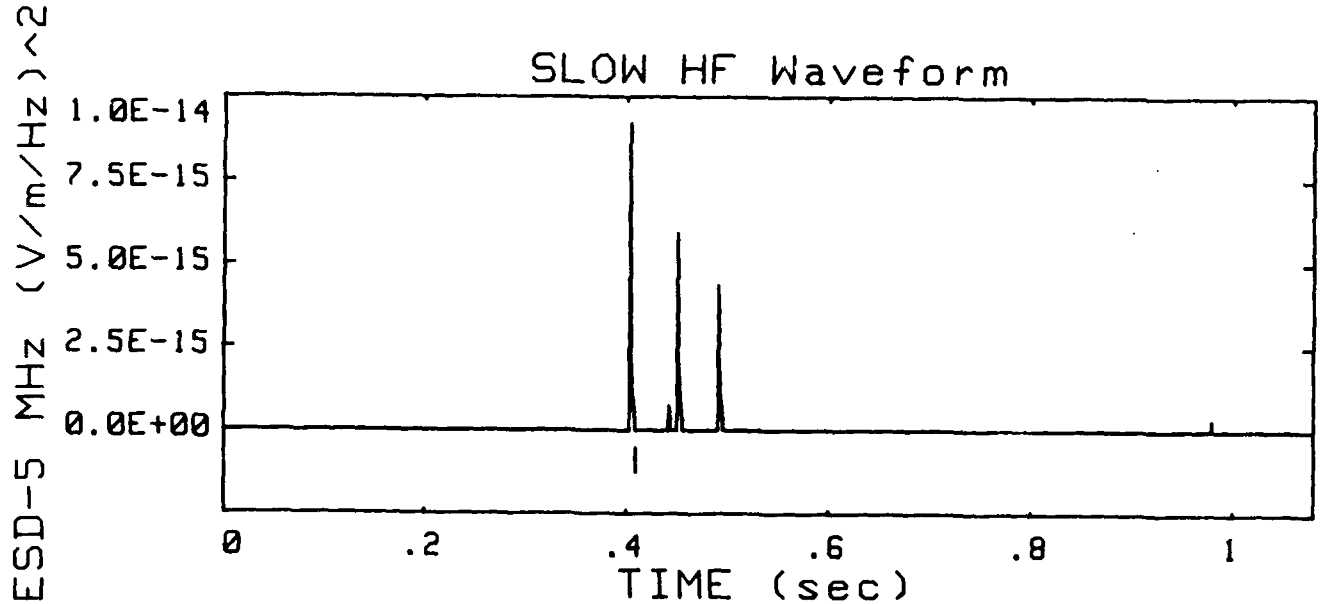


226175352.271 1985 1st RS (34.1 Km)

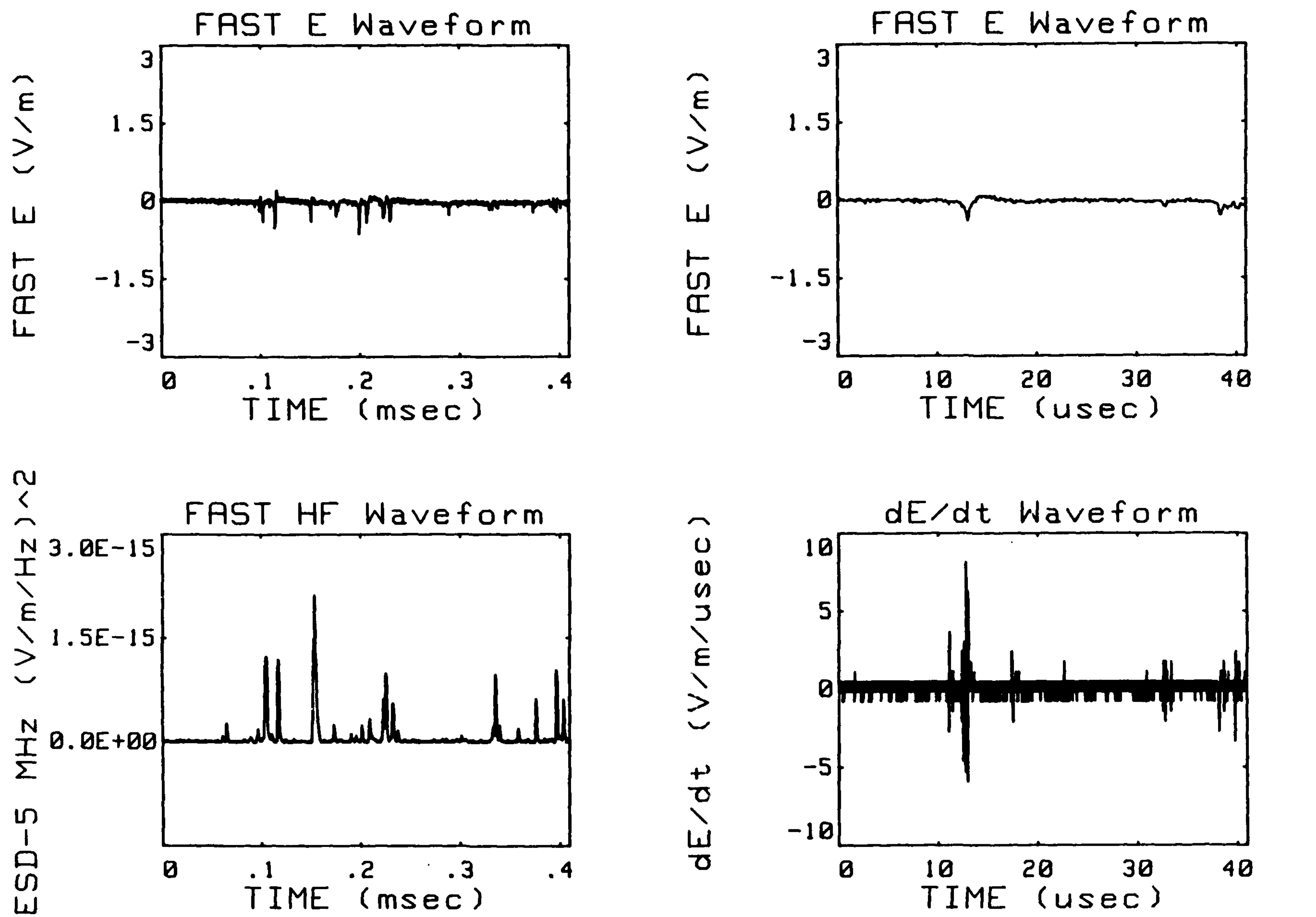


17:53:51.875 14 Aug 1985 (34.1 Km)

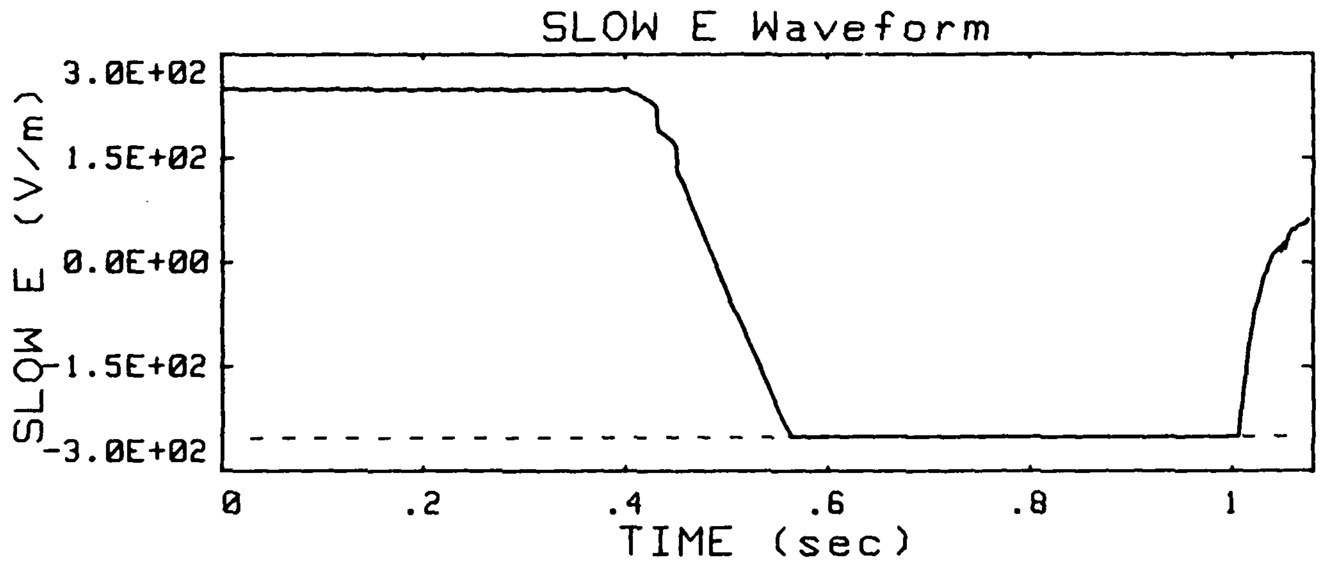


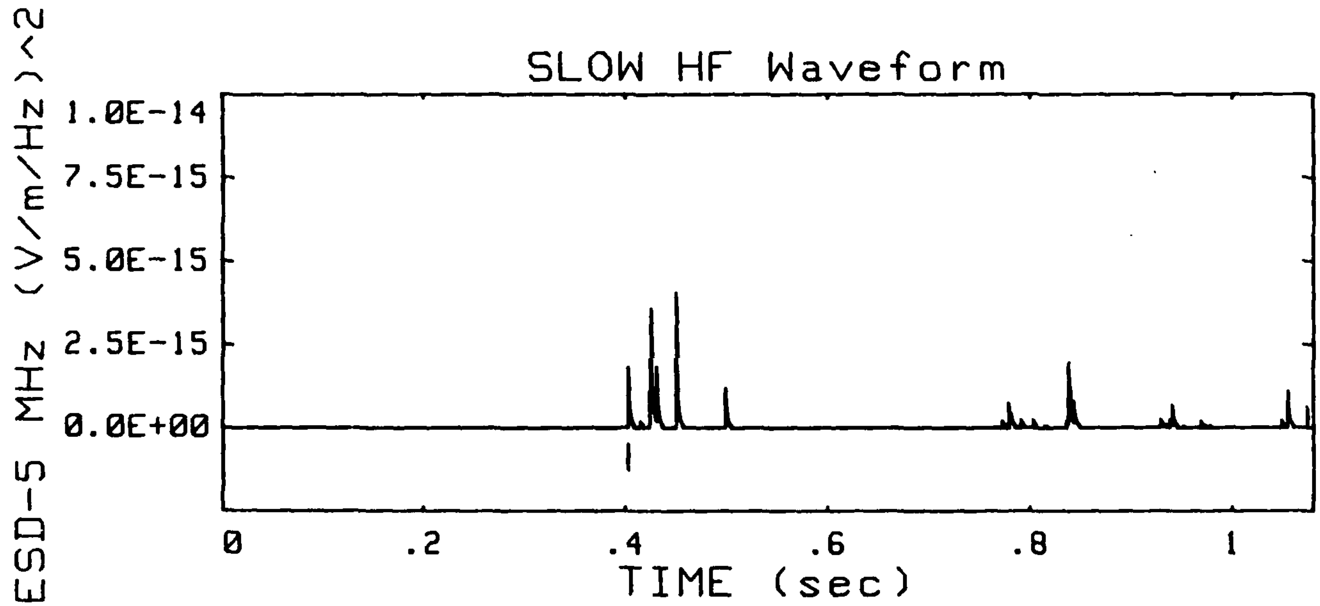


226175535.681 1985 Char Cloud Pulse (15.5 Km)

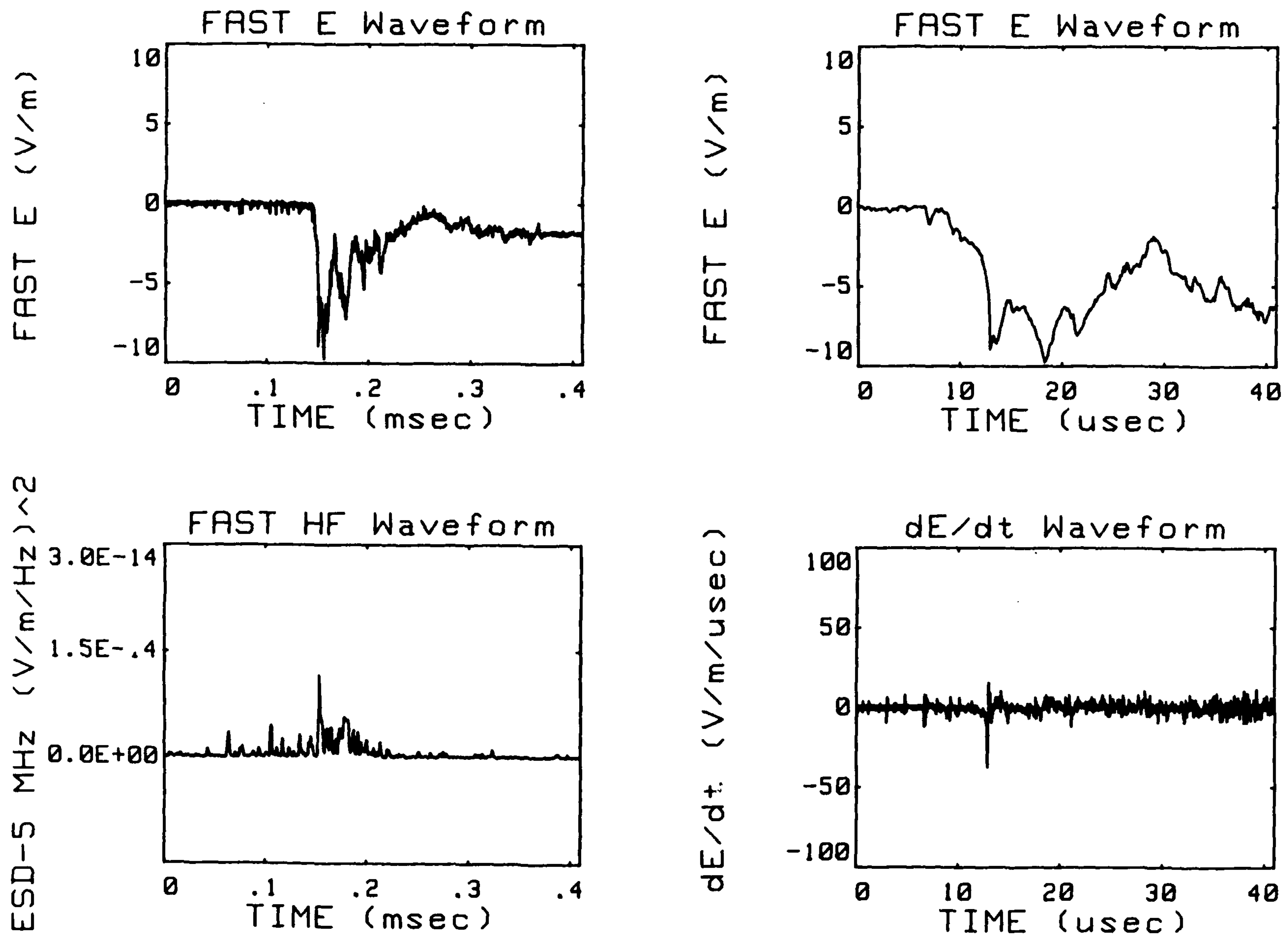


17:55:35.291 14 Aug 1985 (15.5 Km)

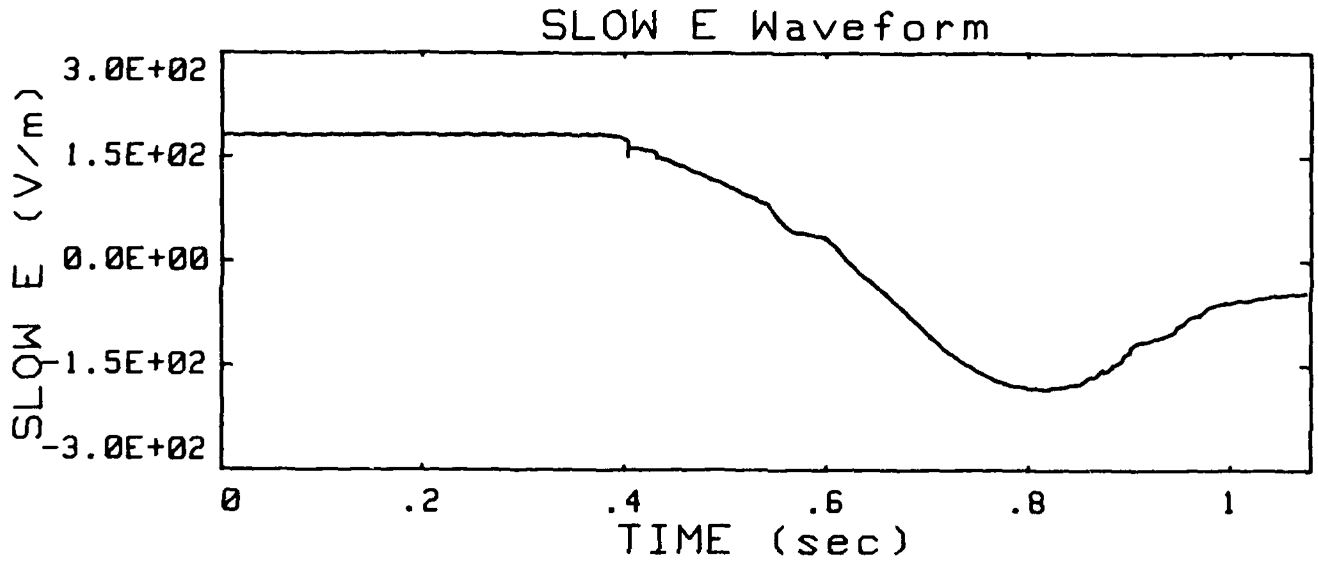


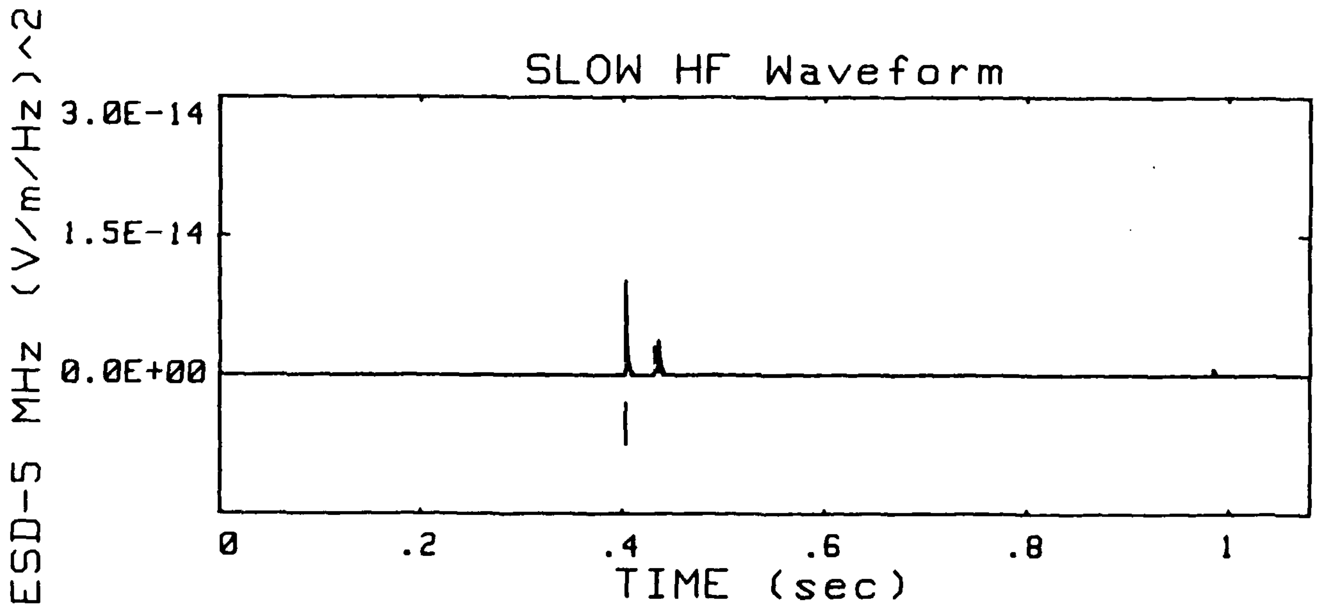


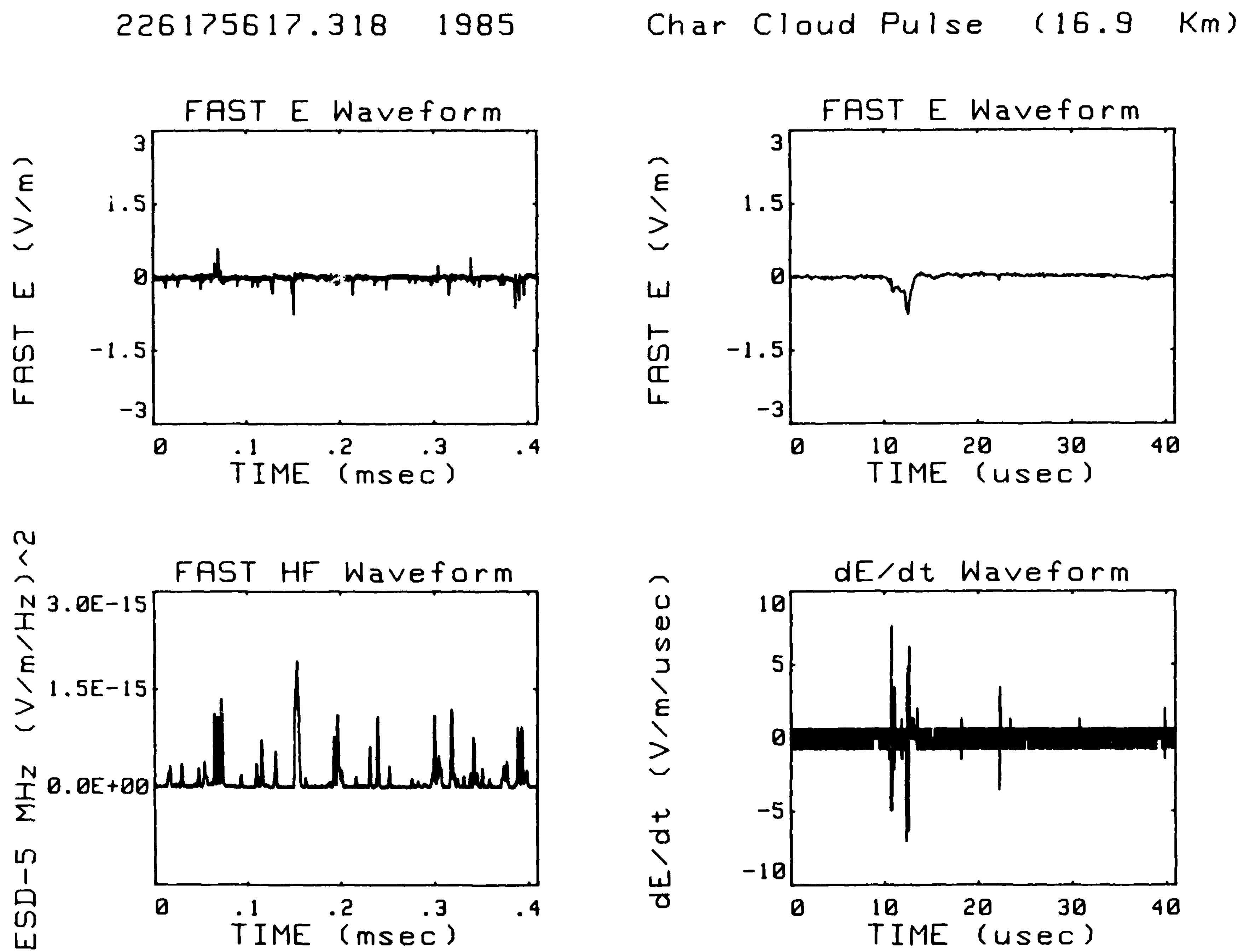
226175551.067 1985 1st RS (32.0 Km)



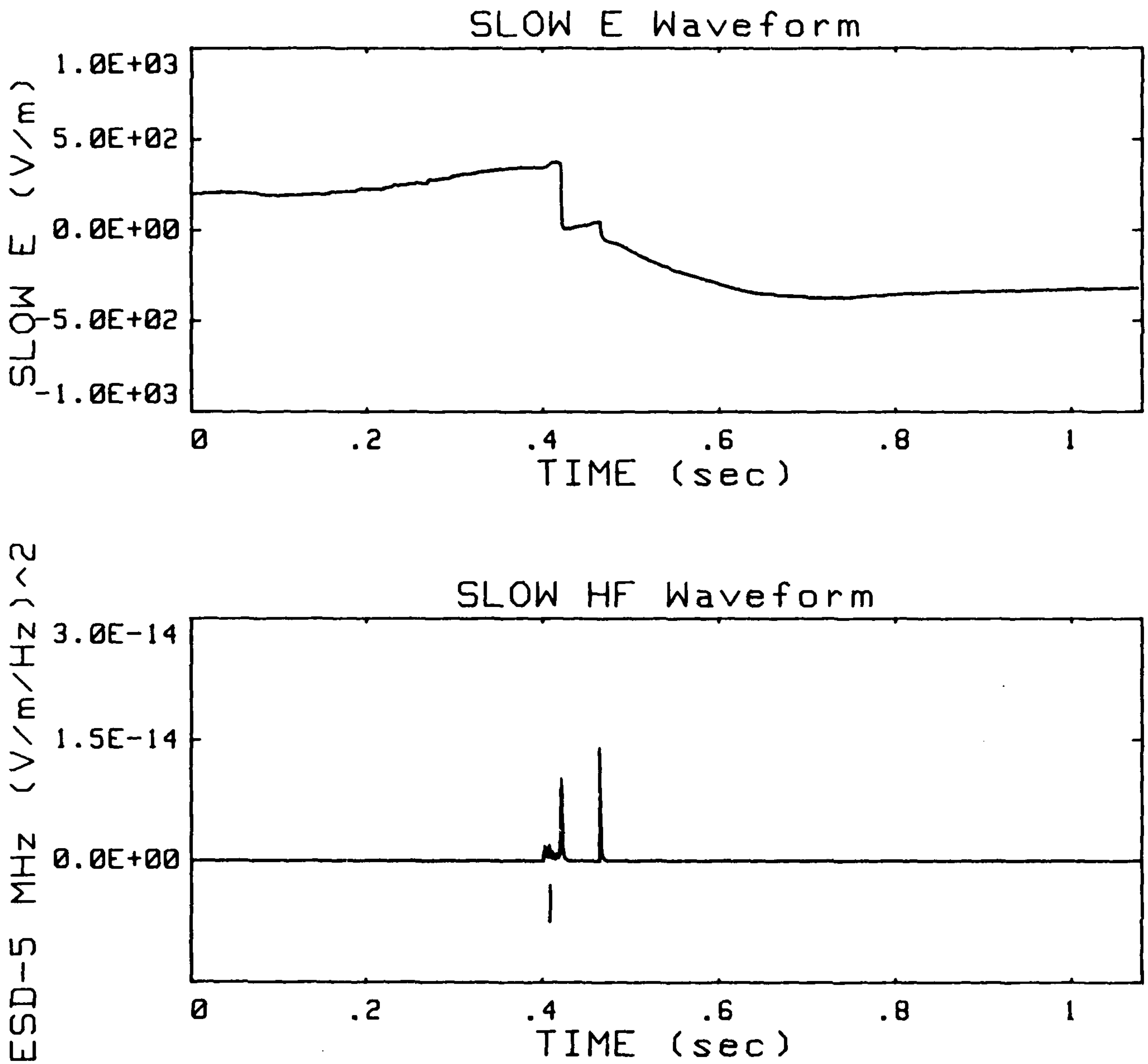
17:55:50.677 14 Aug 1985 (32.0 Km)

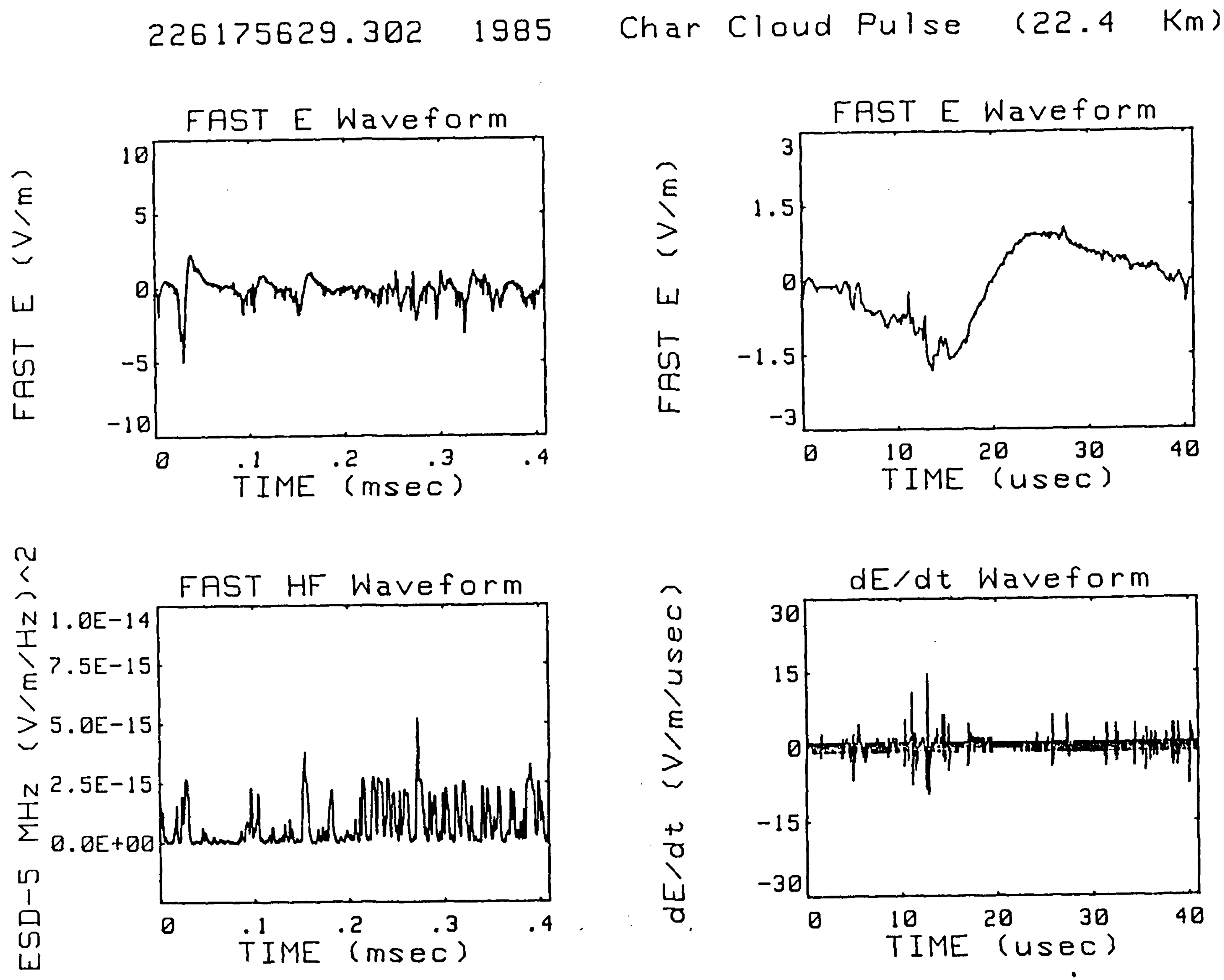





226175617.318 1985
Char Cloud Pulse (16.9 Km)
FAST E Waveform
FAST E (V/m)
3
1.5
0
-1.5
-3
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
3
1.5
0
-1.5
-3
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
3.0E-15
1.5E-15
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
10
5
0
-5
-10
0
10
20
30
40
TIME (usec)

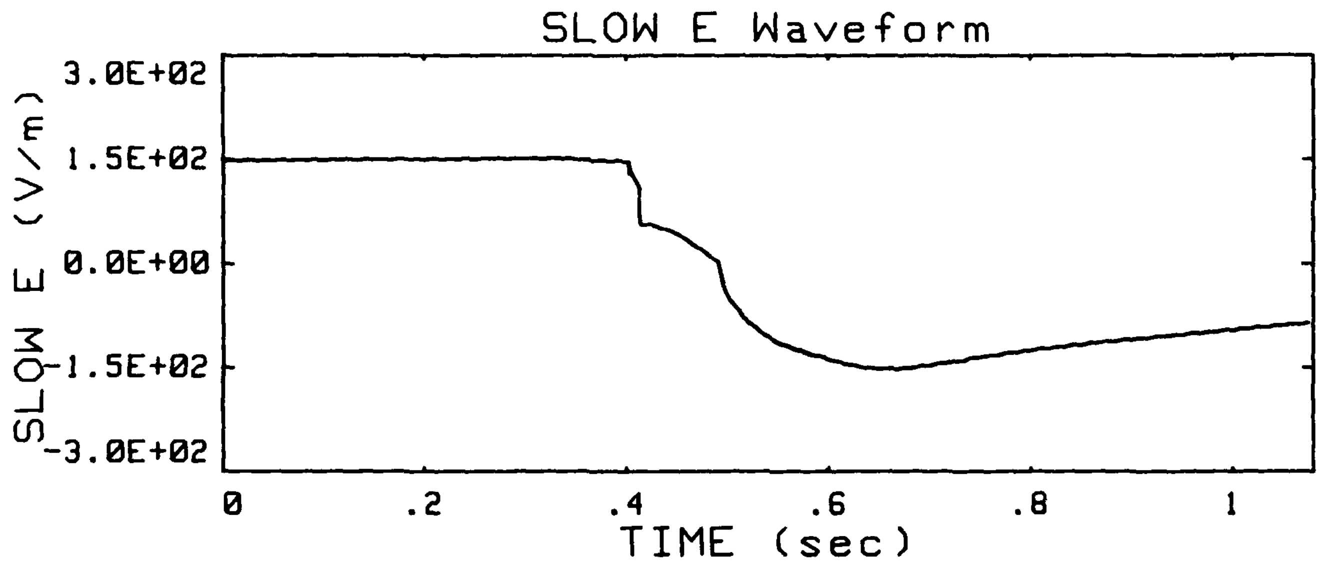
17:56:16.922 14 Aug 1985 (16.9 Km)

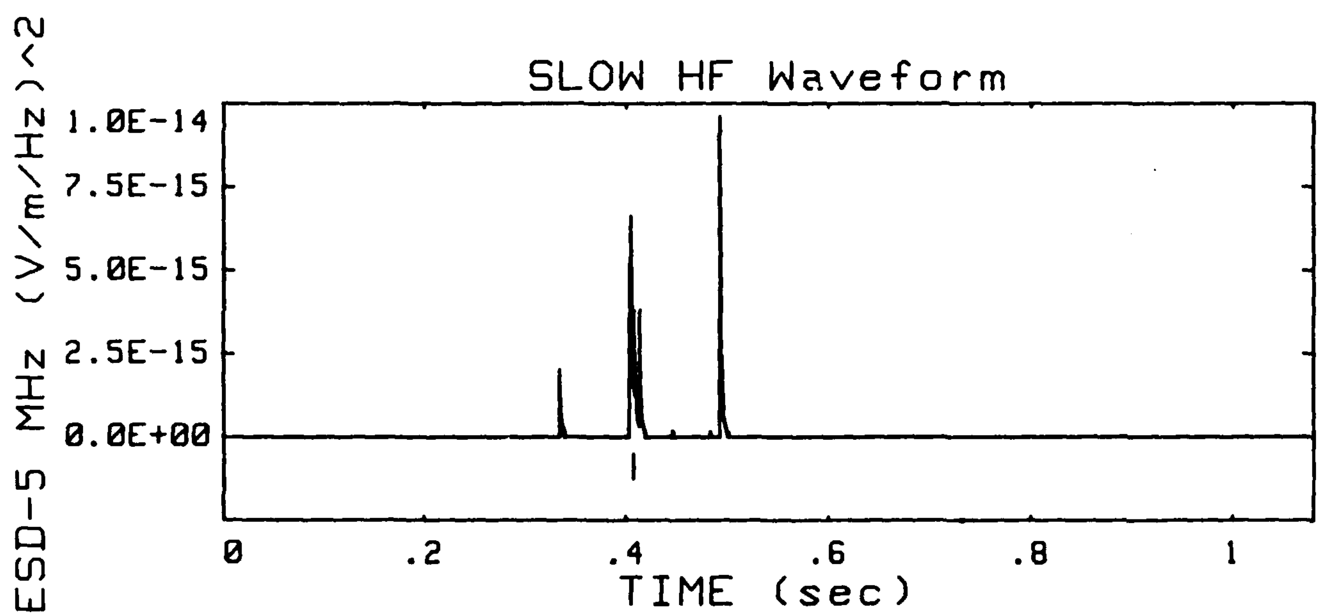




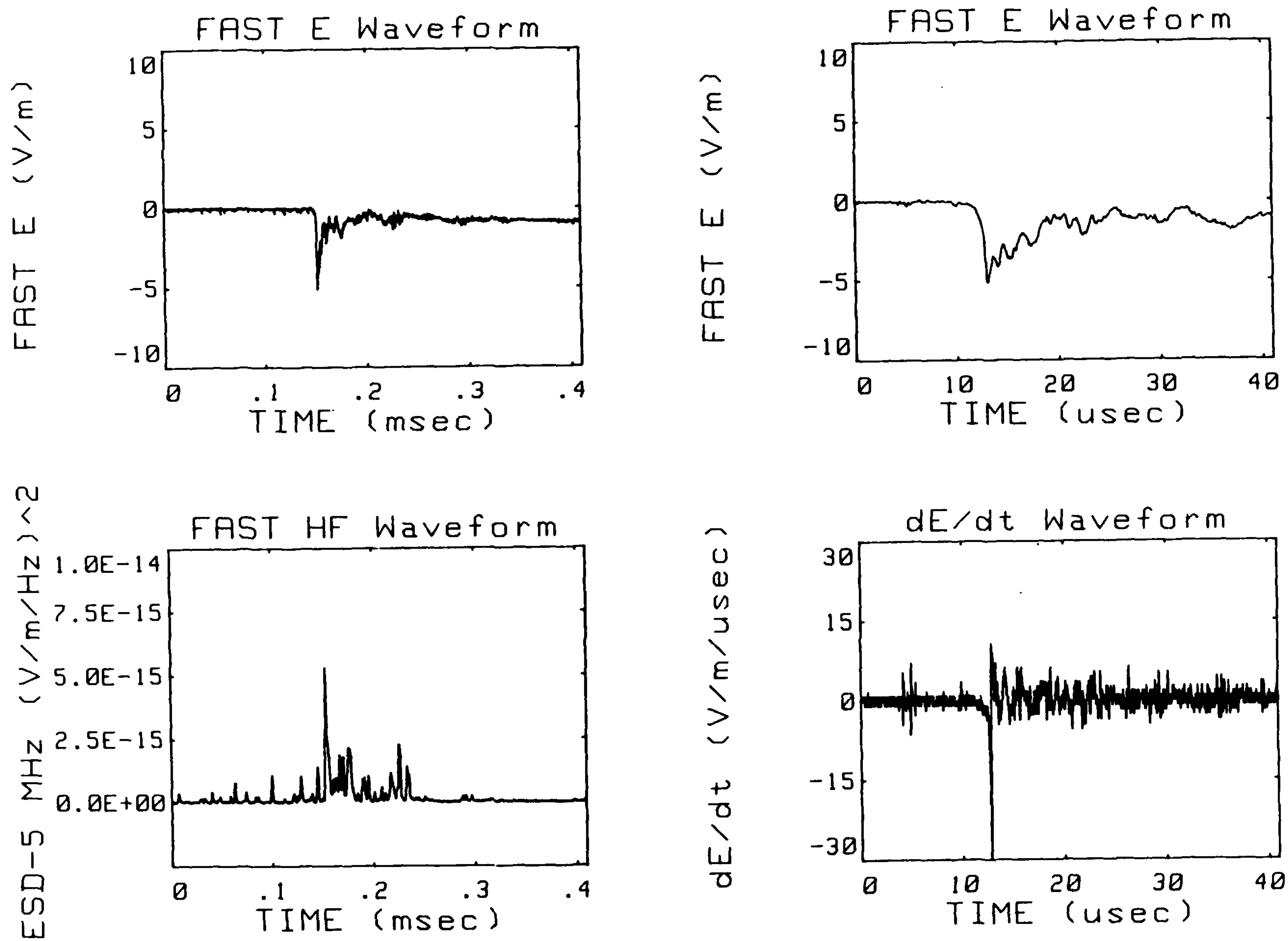
226175629.302 1985 Char Cloud Pulse (22.4 Km)
FAST E Waveform
FAST E (V/m)
10
5
0
-5
-10
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
3
1.5
0
-1.5
-3
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
1.0E-14
7.5E-15
5.0E-15
2.5E-15
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
30
15
0
-15
-30
0
10
20
30
40
TIME (usec)

17:56:28.908 14 Aug 1985 (22.4 Km)

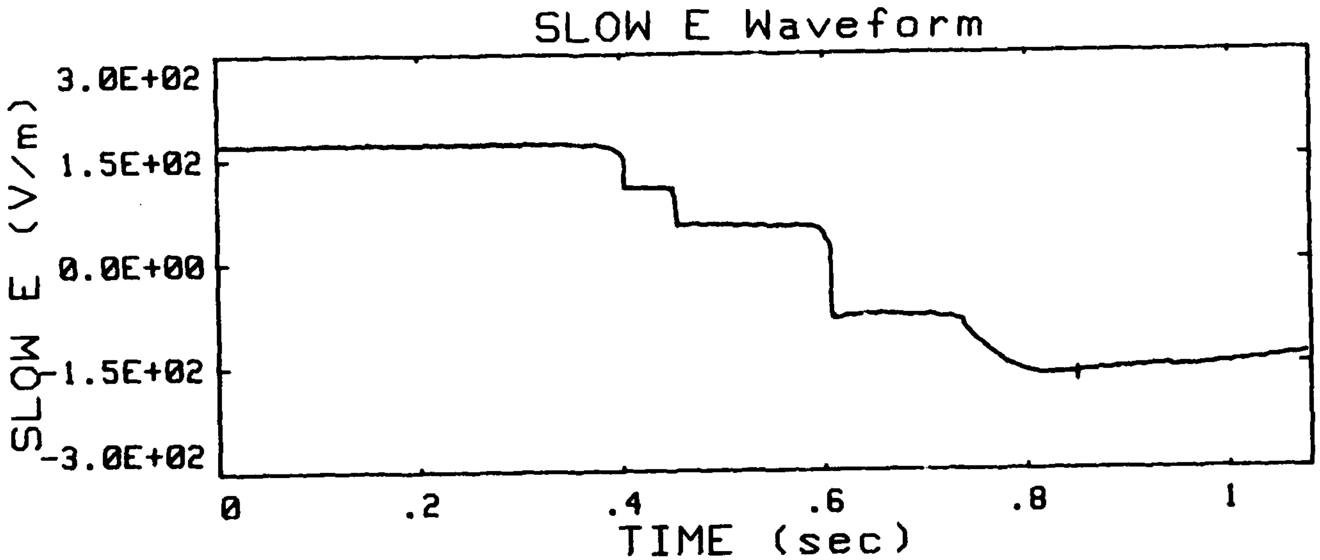


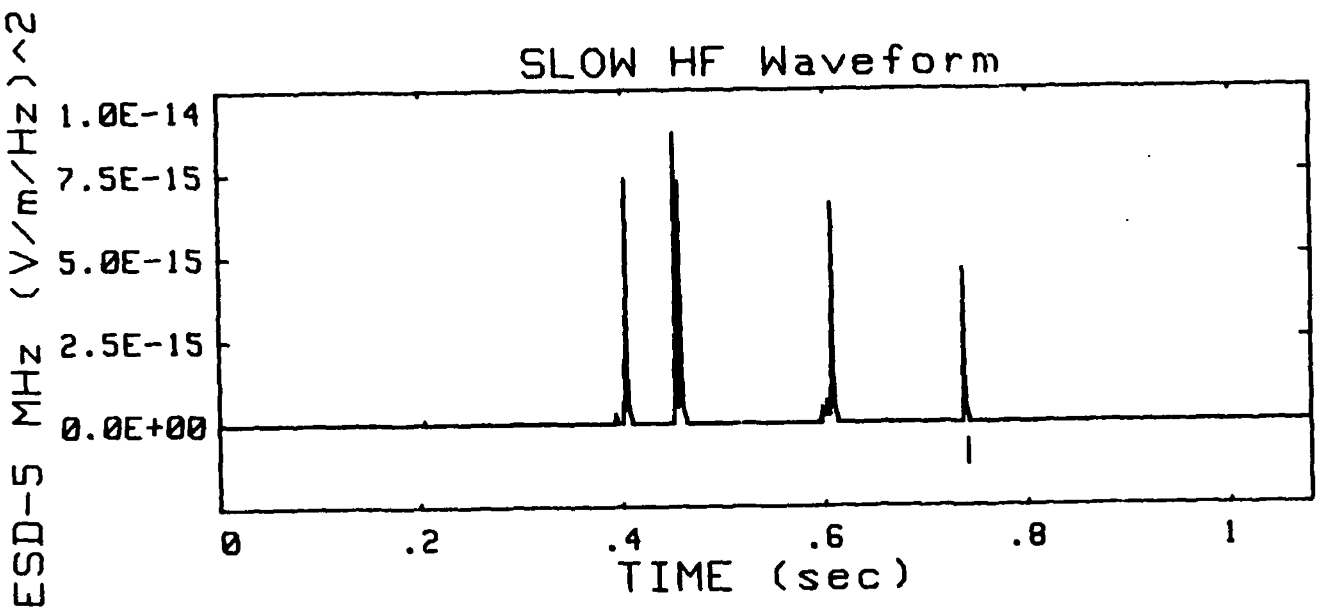


226175719.659 1985 1st RS (21.8 Km)

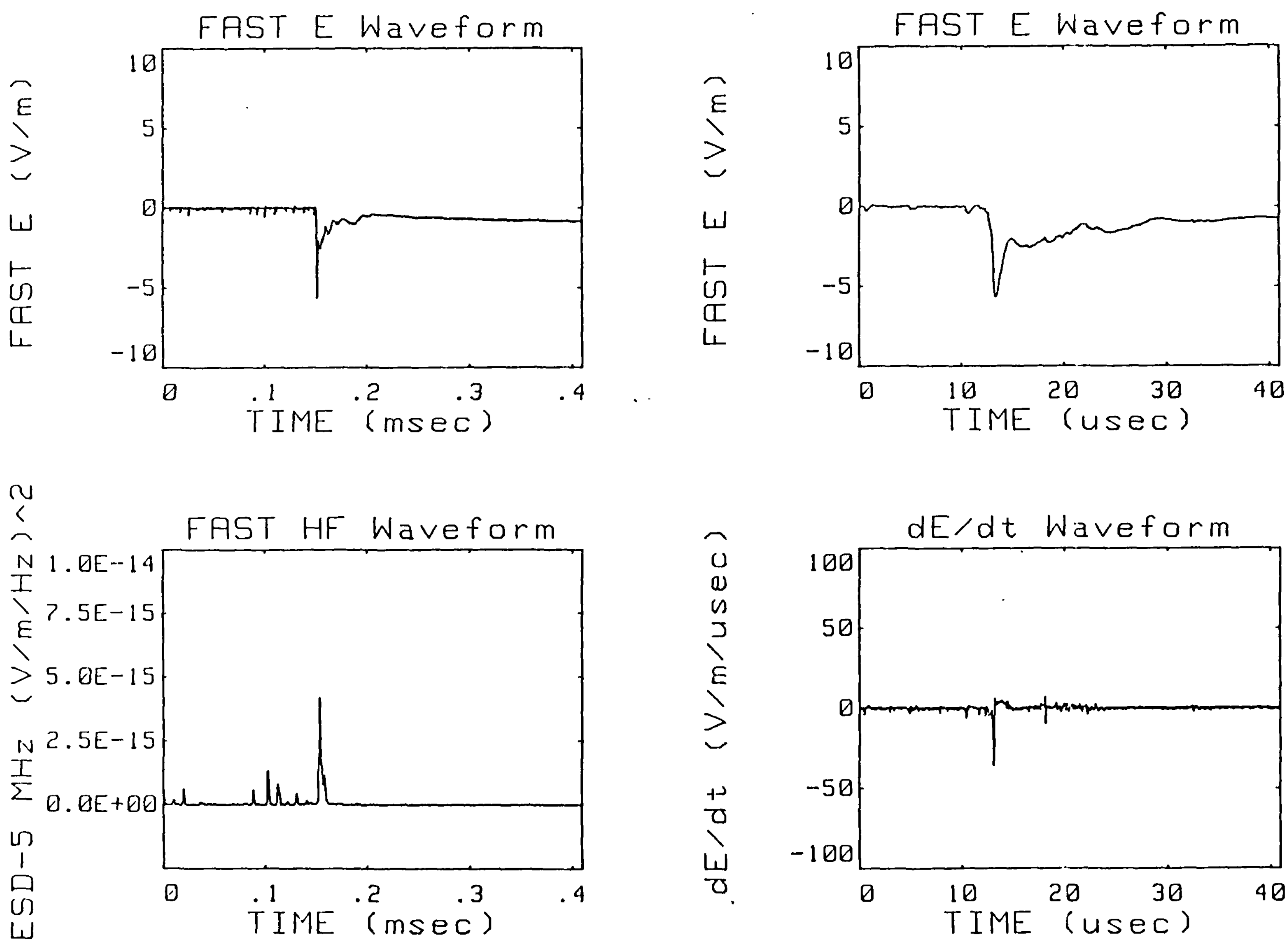


17:57:18.931 14 Aug 1985 (21.8 Km)

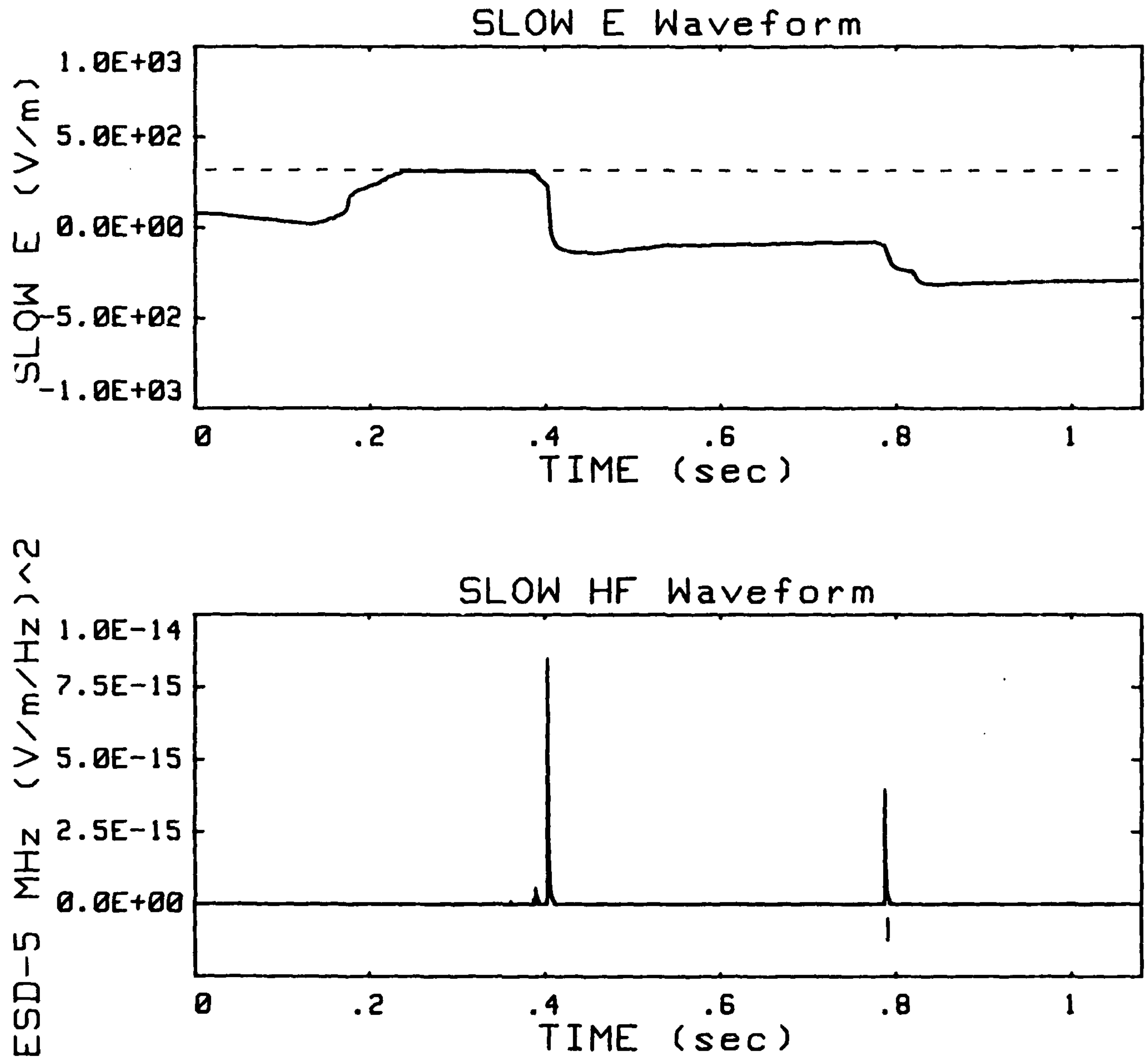




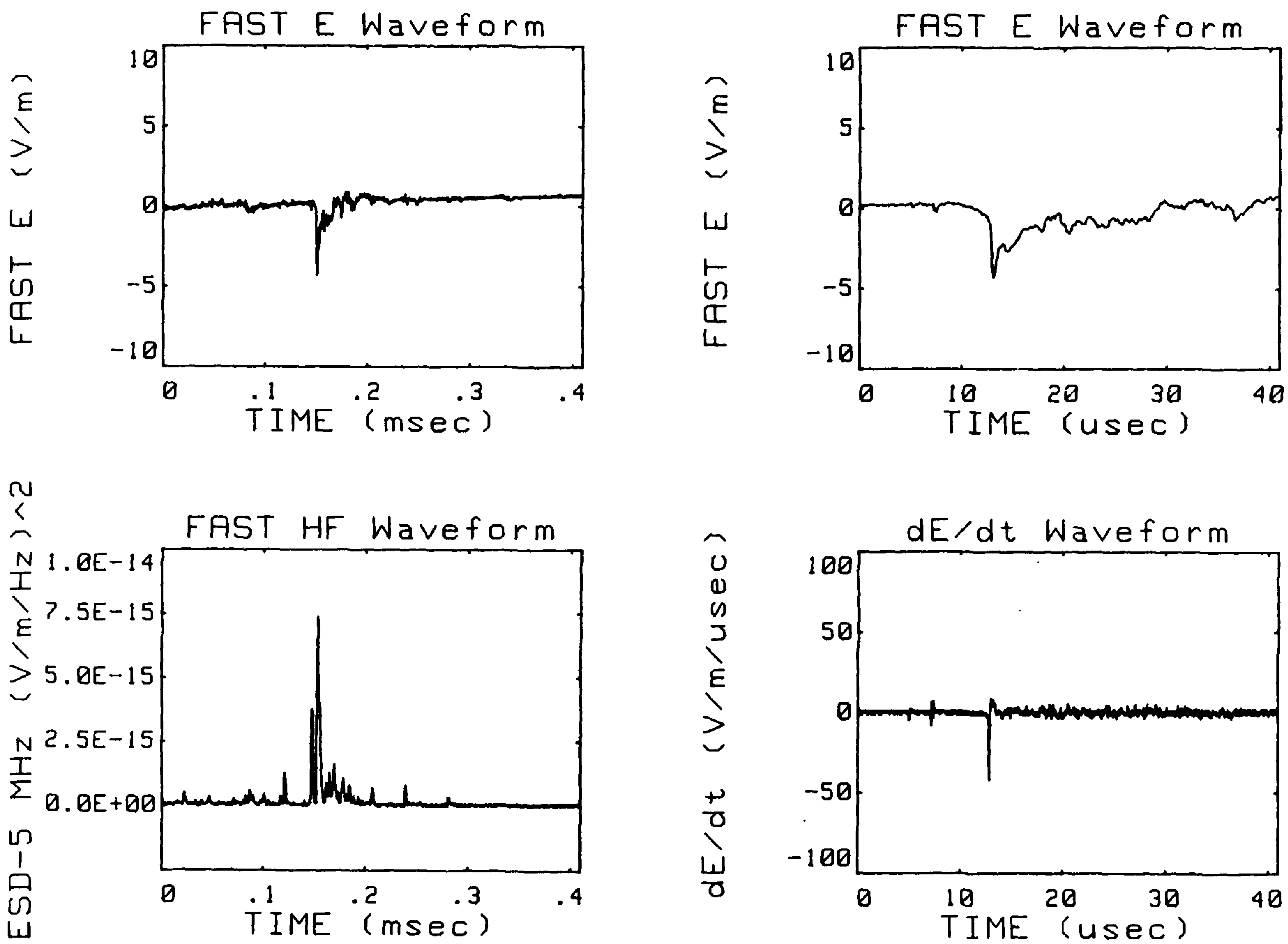
226175734.706 1985 Anomalous #1 RS (17.5 Km)



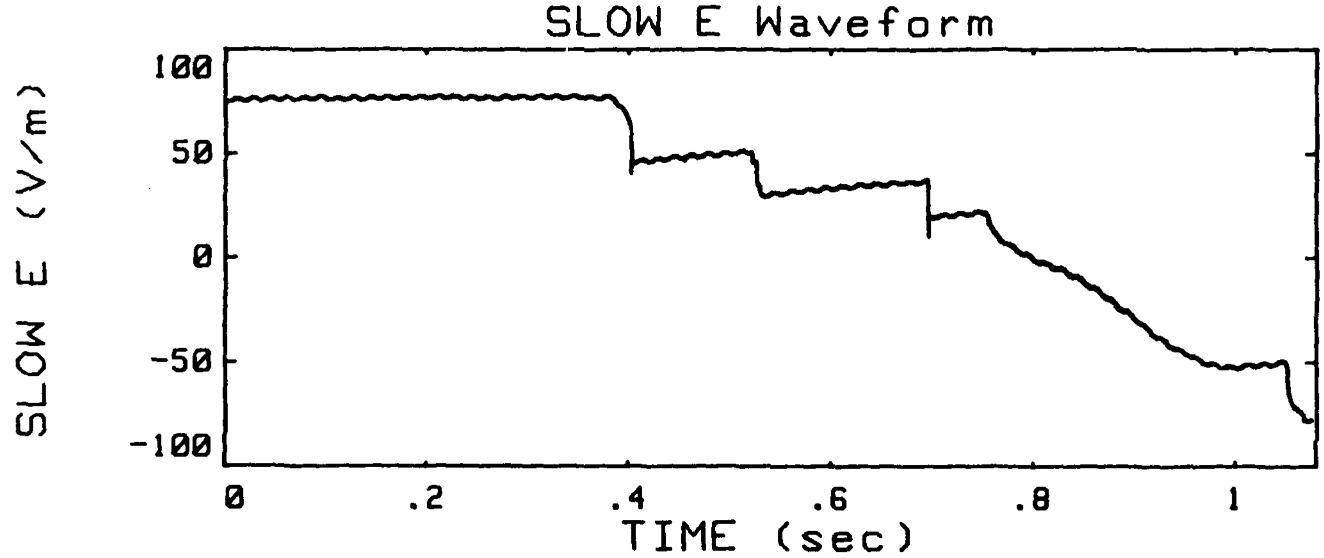
17:57:33.928   14 Aug 1985   (17.5 Km)

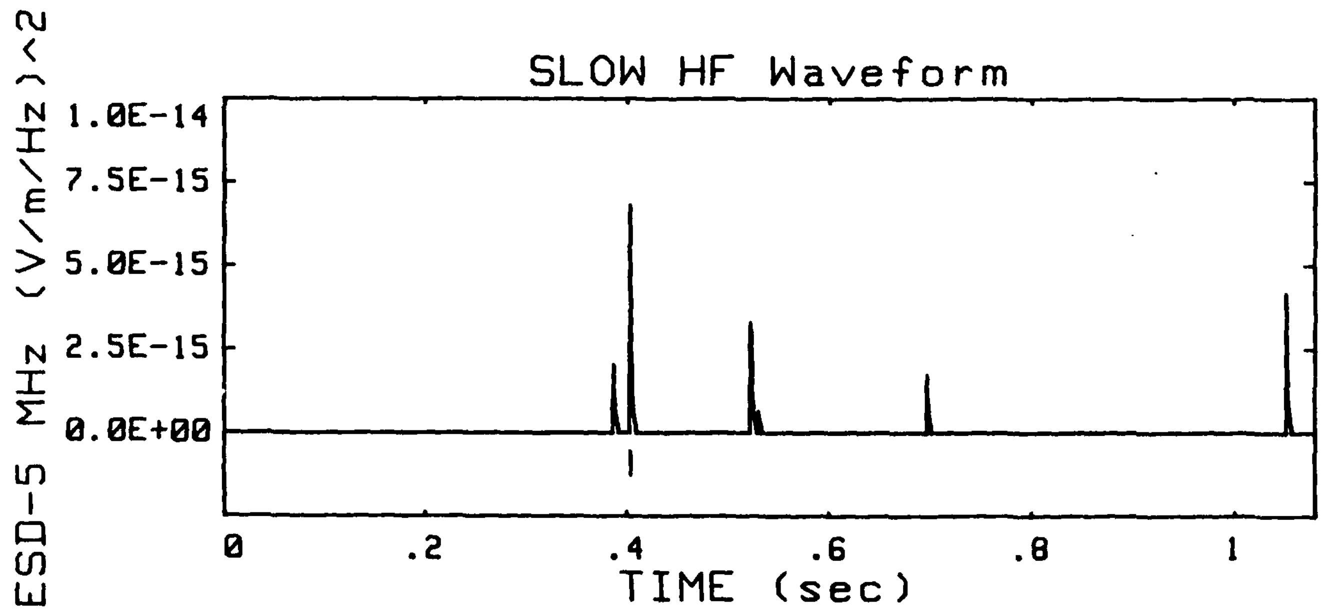


226175742.737 1985 1st RS (28.0 Km)

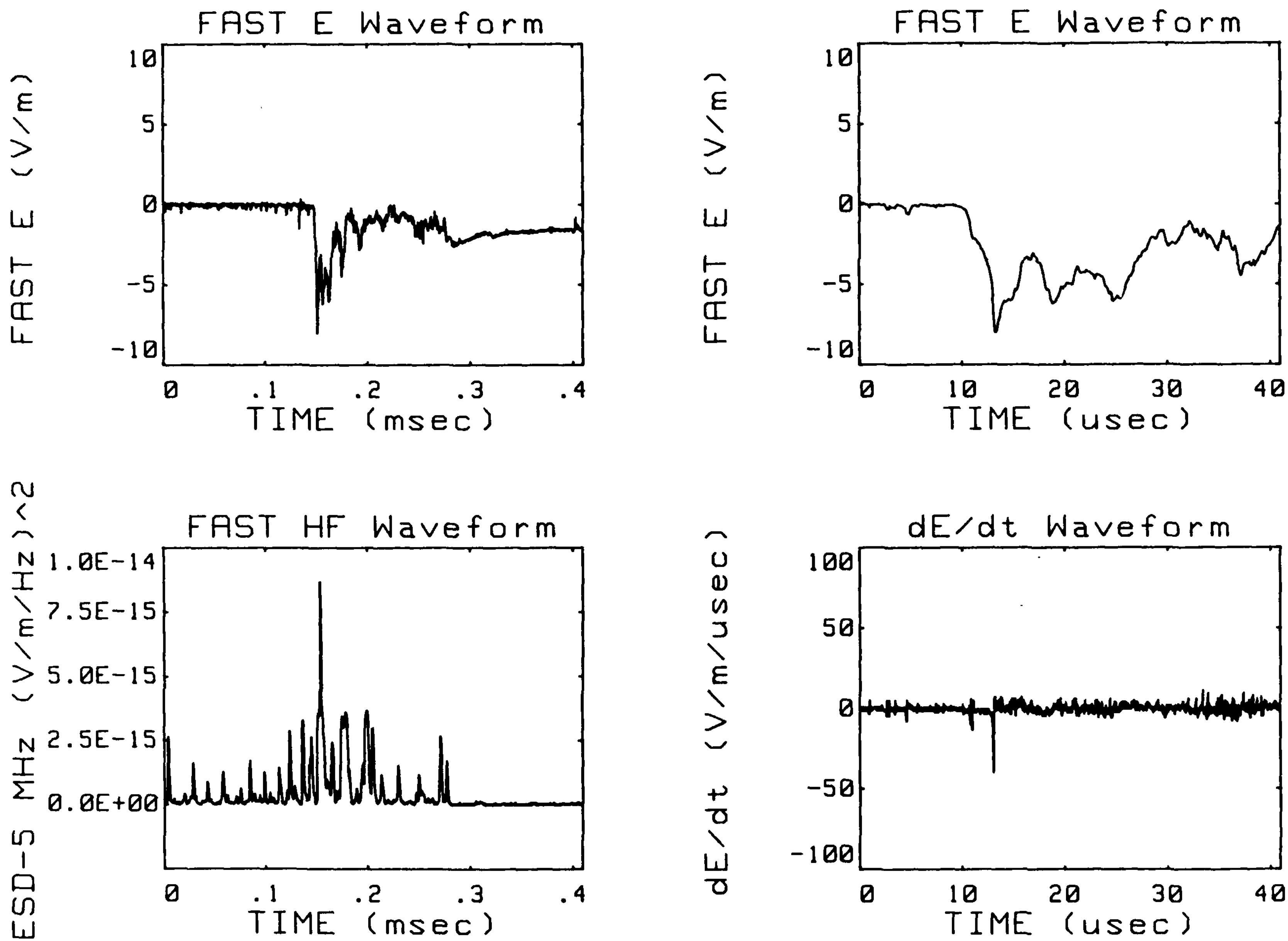


17:57:42.346 14 Aug 1985 (28.0 Km)

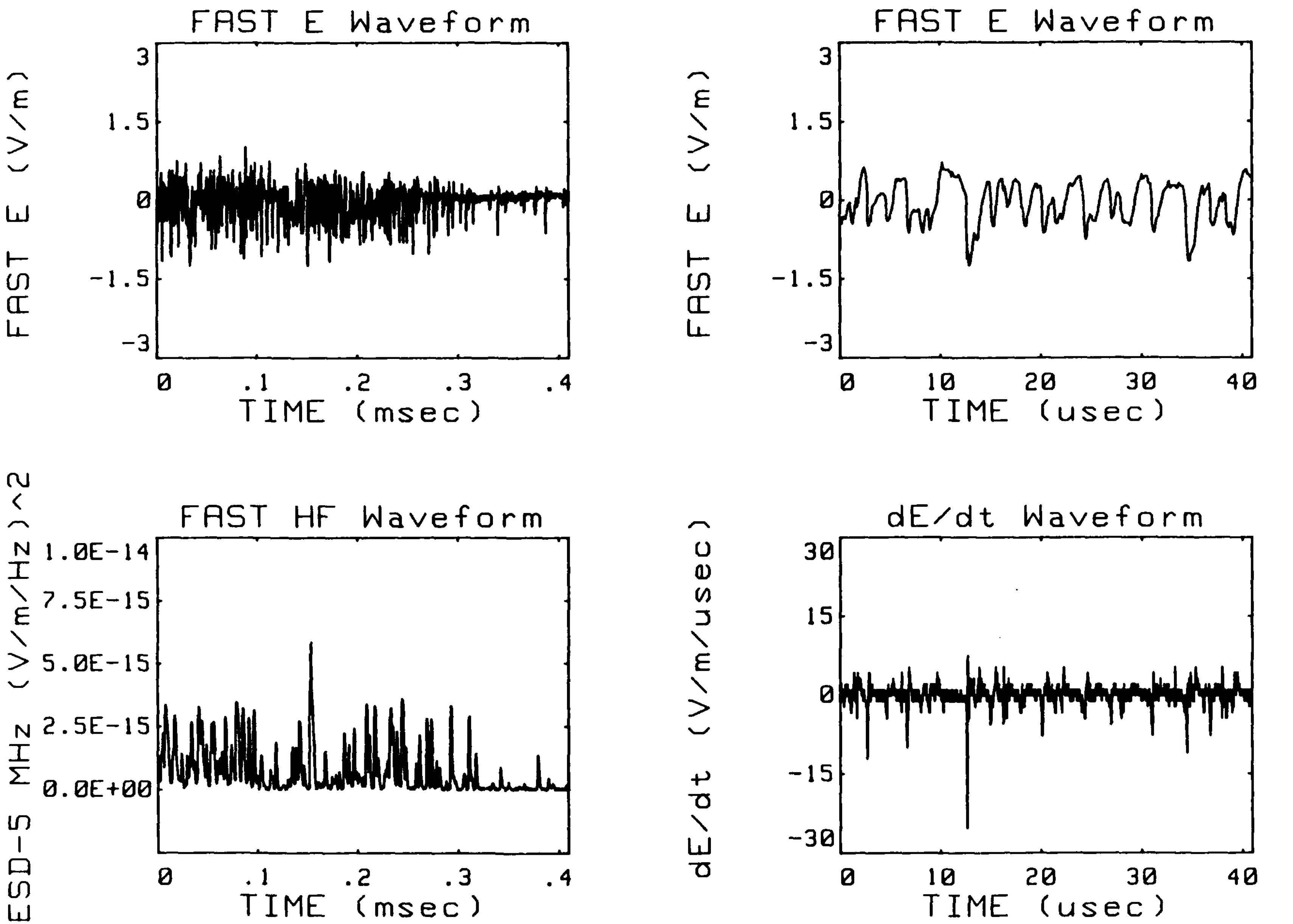




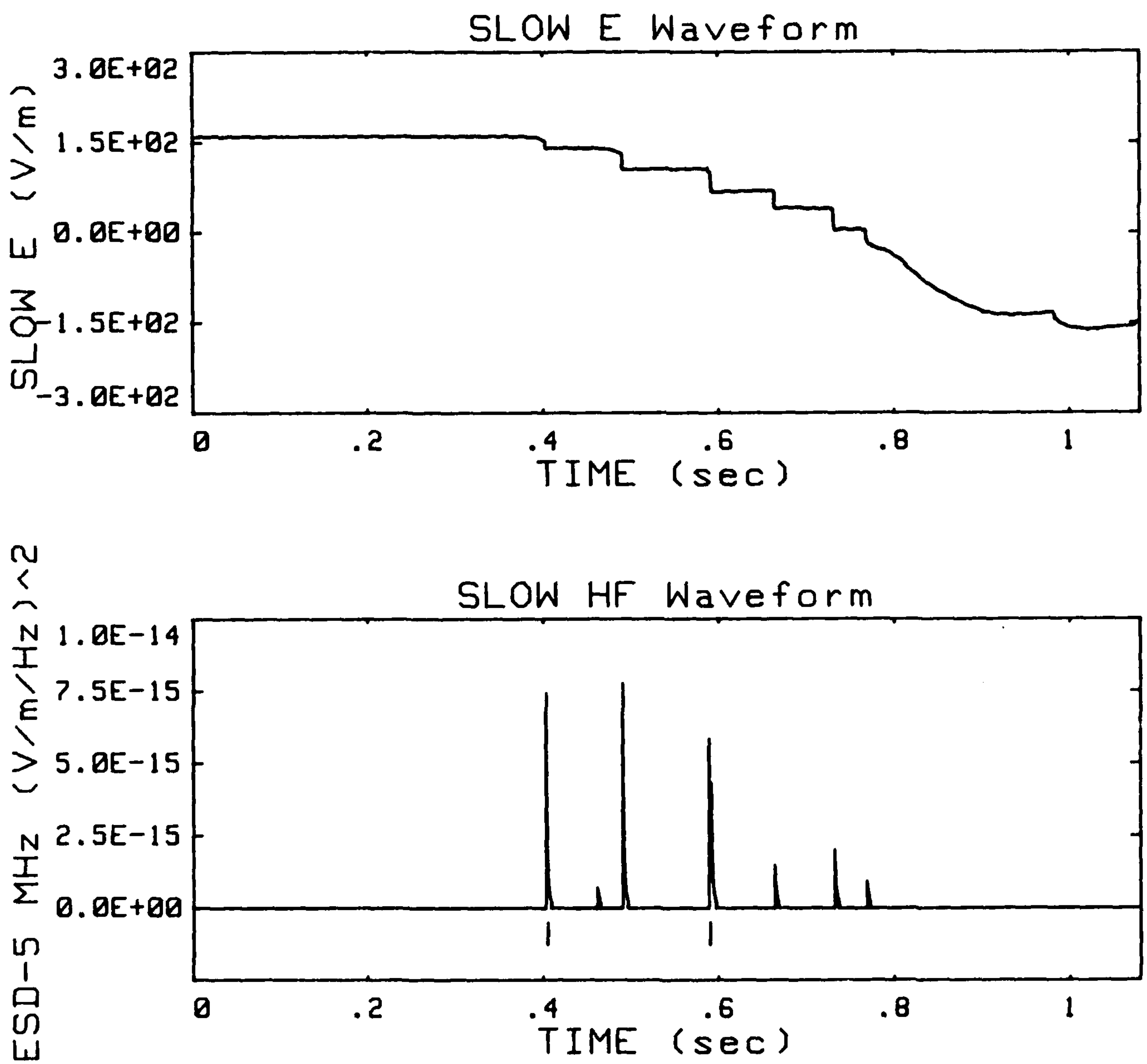
226175754.224   1985   1st RS   (26.4 Km)



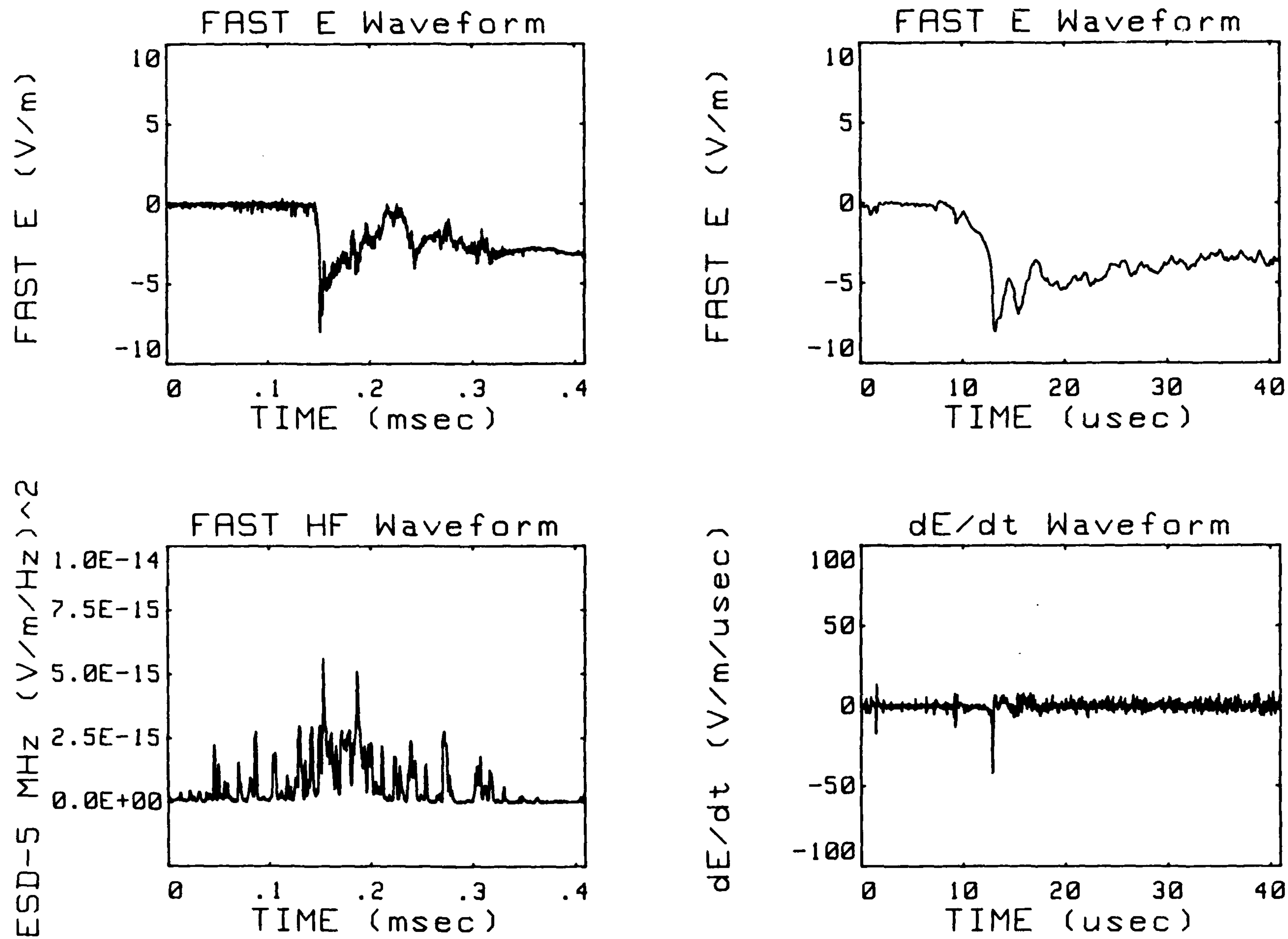
226175754.410 1985 Chaotic Leader (26.4 Km)



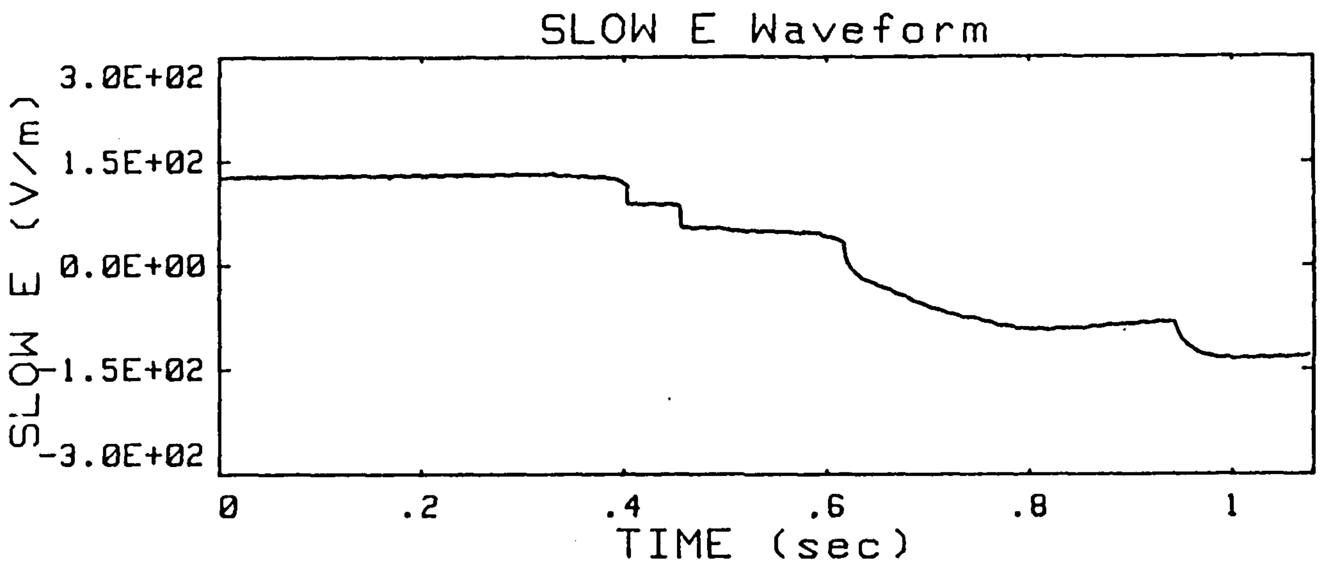
17:57:53.832 14 Aug 1985 (26.4 Km)

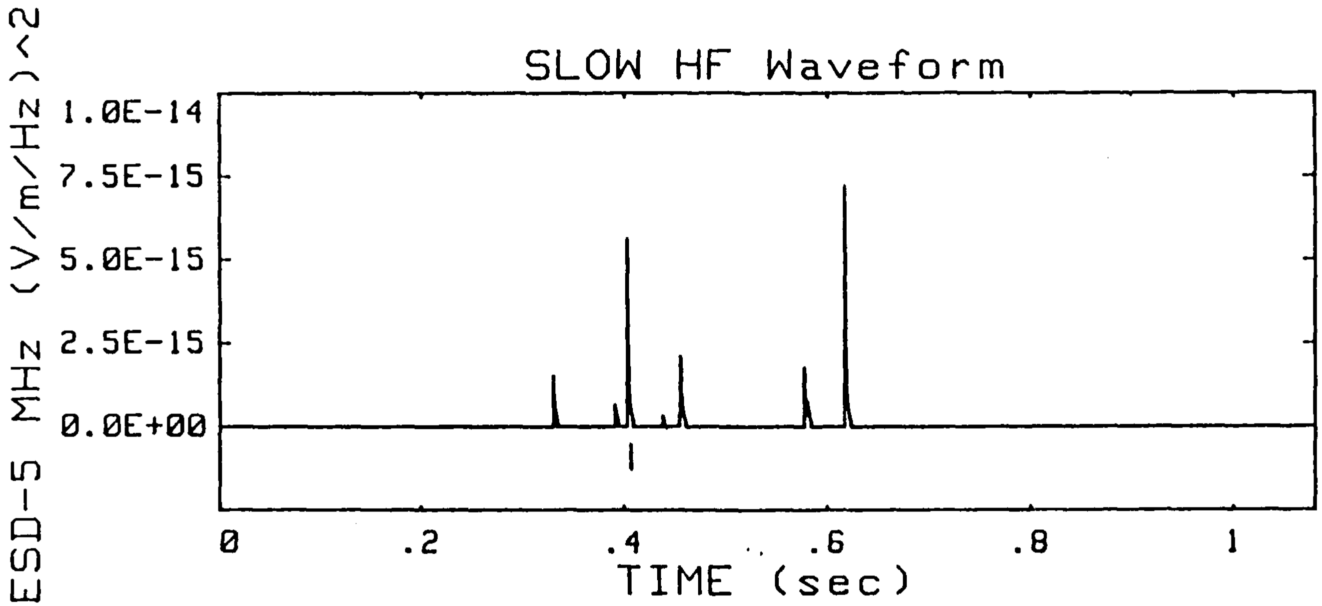


226175804.206 1985 1st RS (24.0 Km)

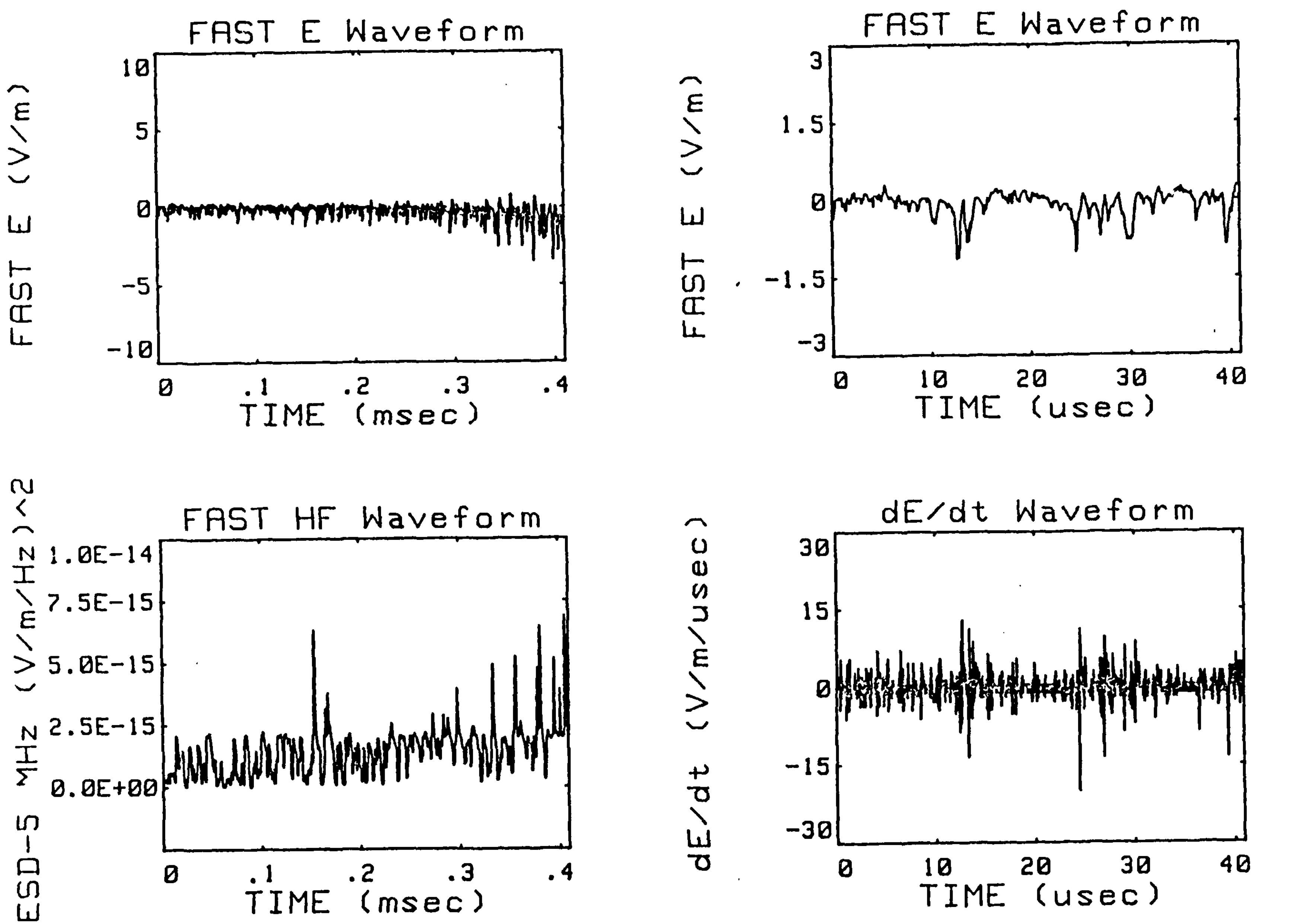


17:58:03.812 14 Aug 1985 (24.0 Km)

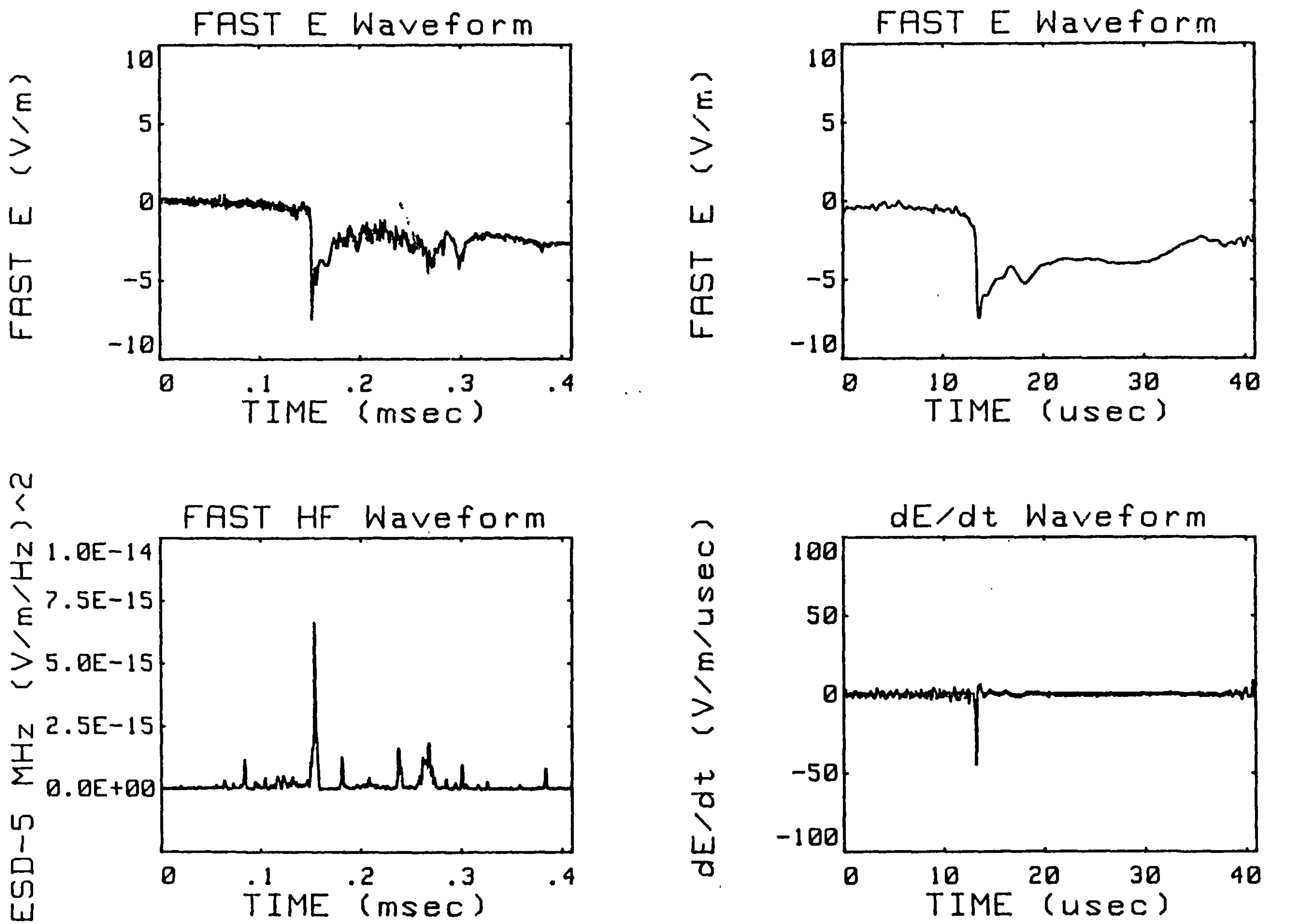




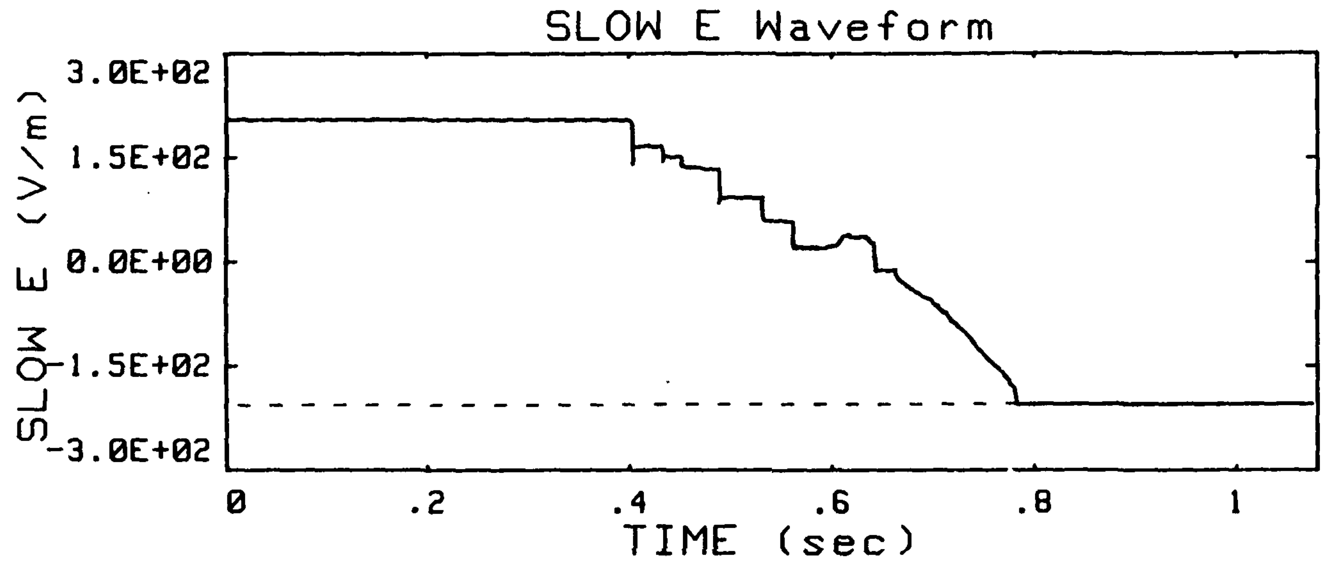
226175829.004 1985 Stepped Leader (19.9 Km)

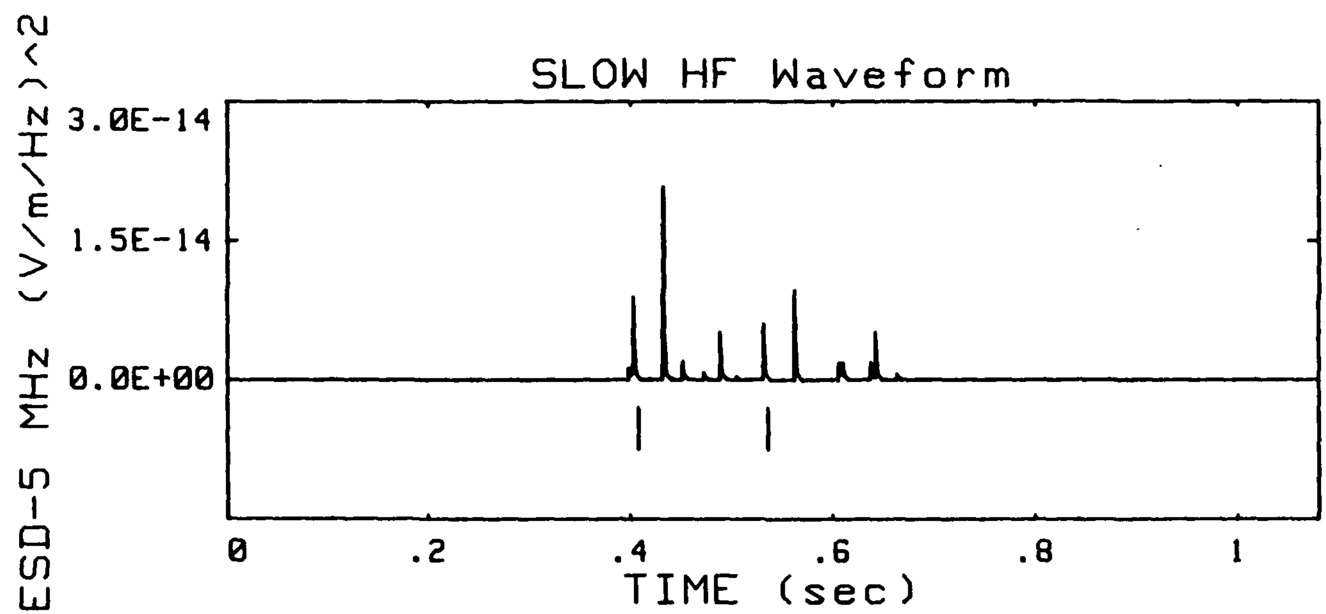


226175829.133 1985 Anomalous #2 RS (19.9 Km)

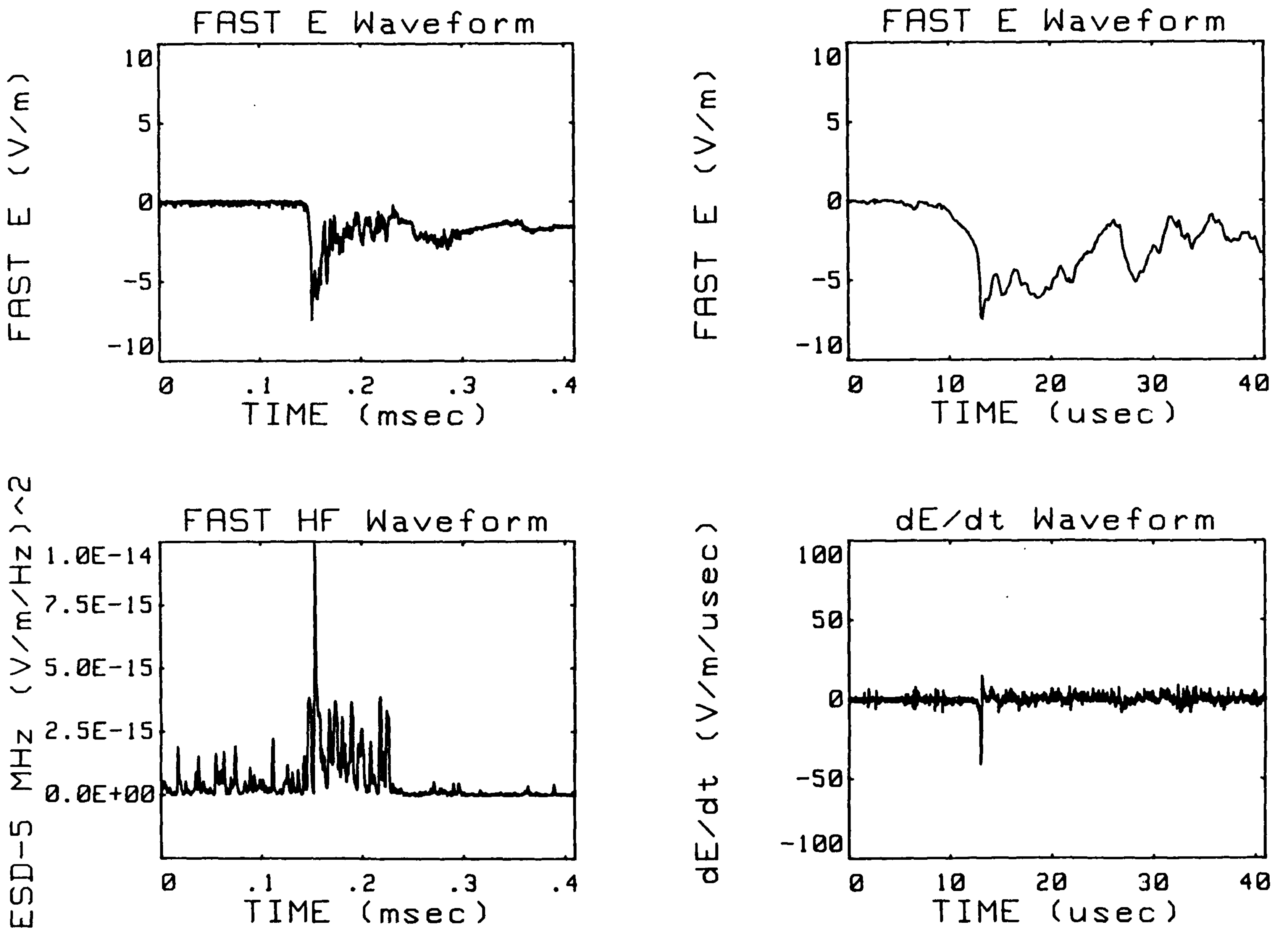


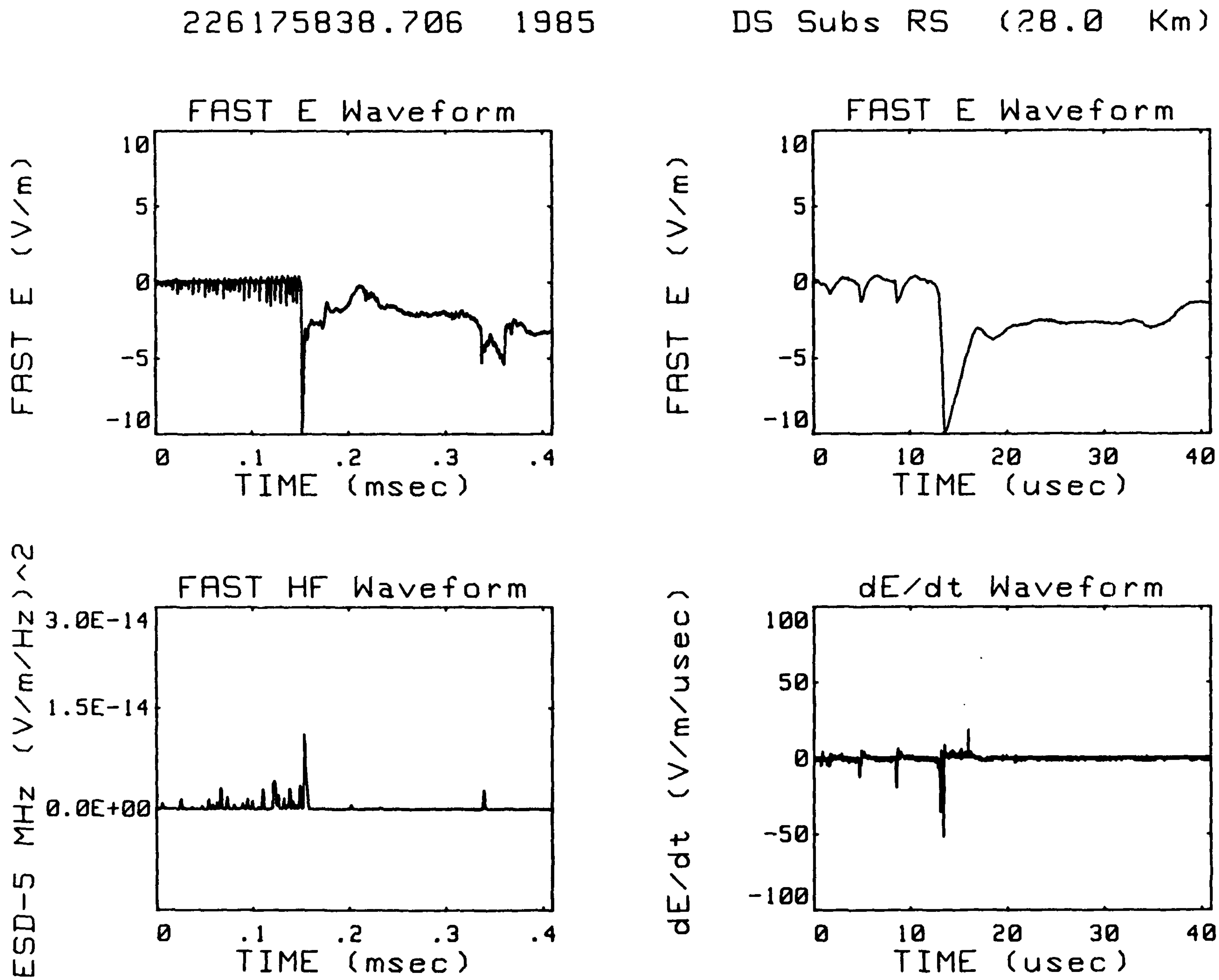
17:58:28.609 14 Aug 1985 (19.9 Km)





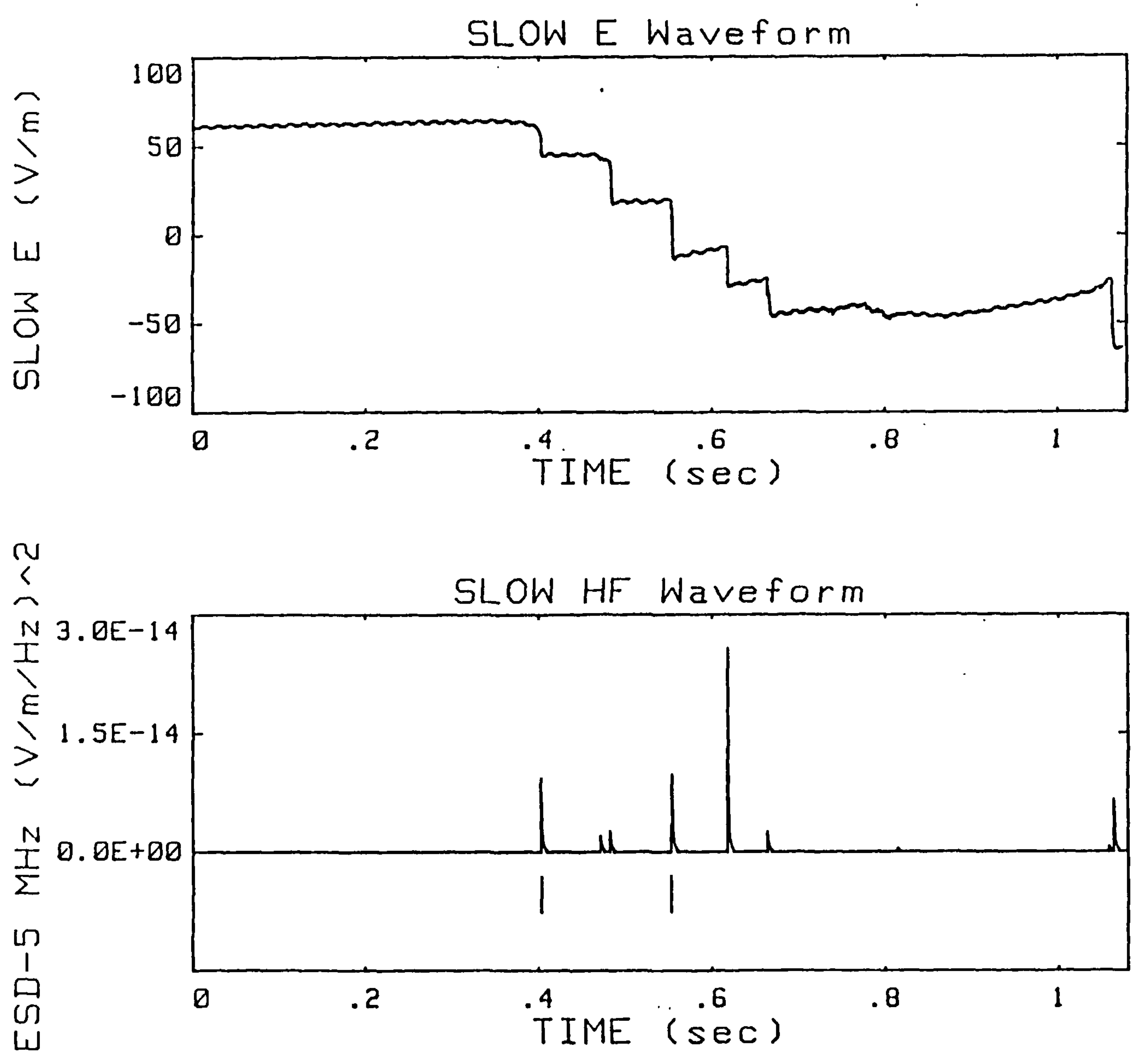
226175838.556   1985   1st RS   (28.0 Km)



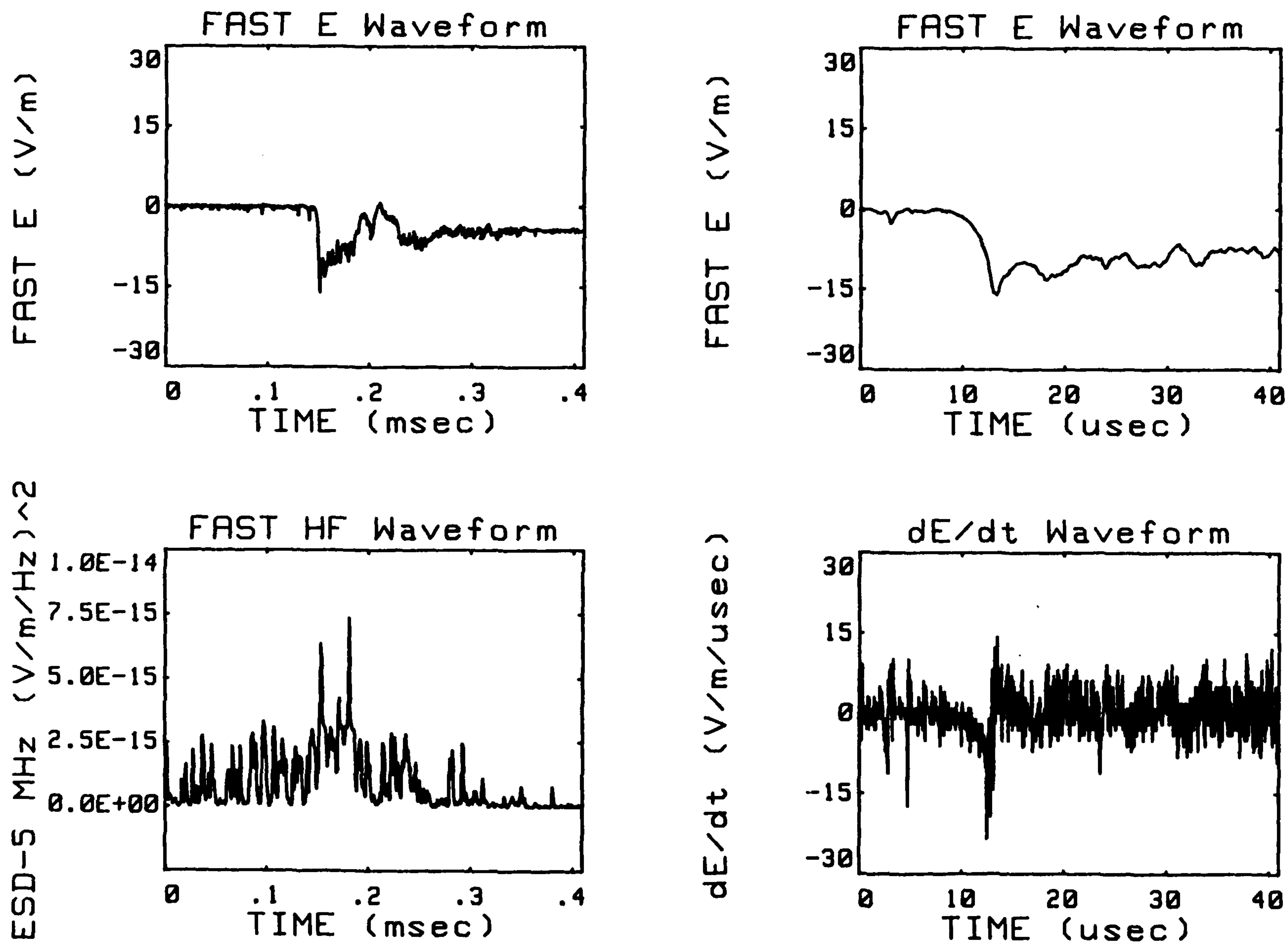


226175838.706 1985
DS Subs RS (28.0 Km)
FAST E Waveform
FAST E (V/m)
10
5
0
-5
-10
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
10
5
0
-5
-10
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
3.0E-14
1.5E-14
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
100
50
0
-50
-100
0
10
20
30
40
TIME (usec)

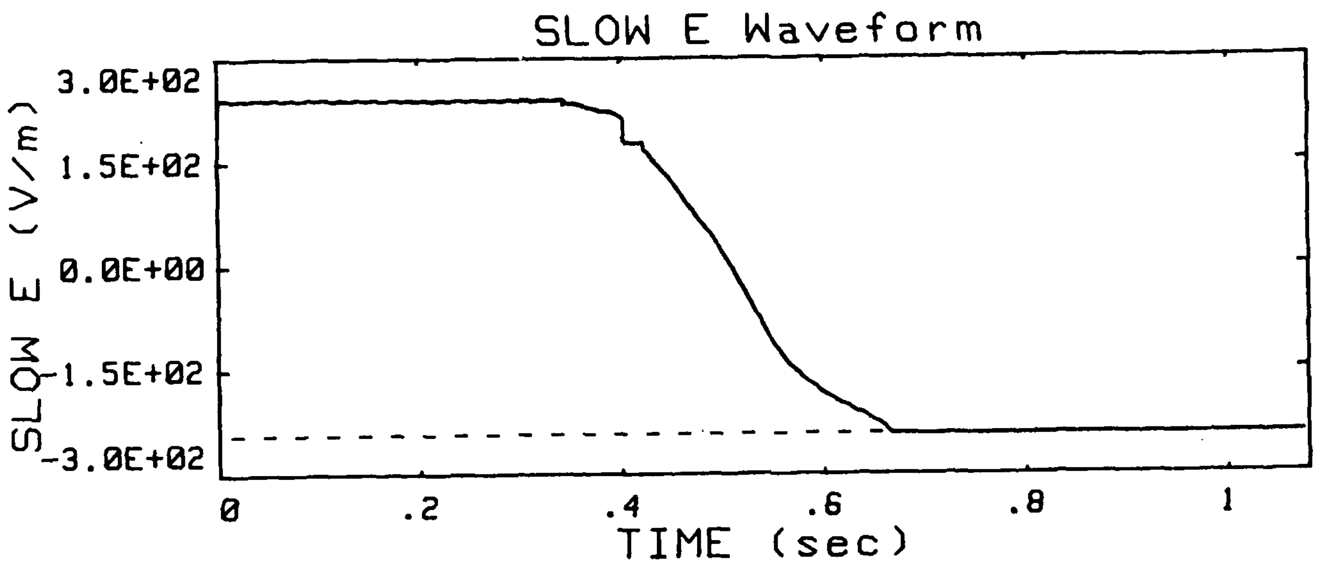
17:58:38.165 14 Aug 1985 (28.0 Km)

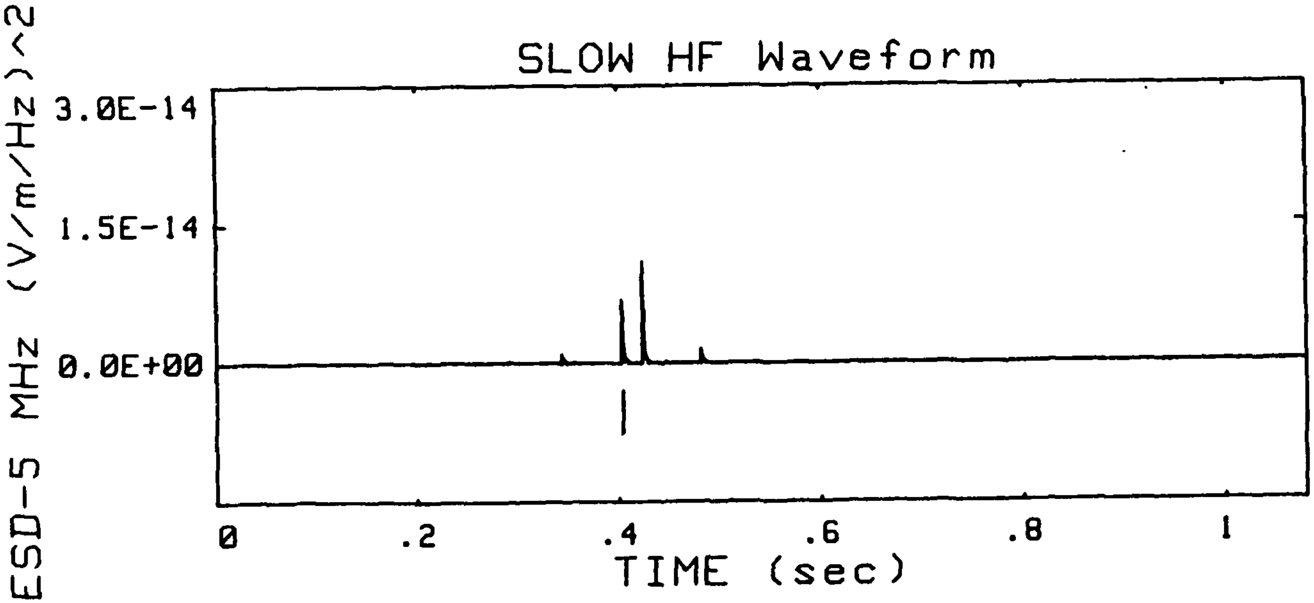


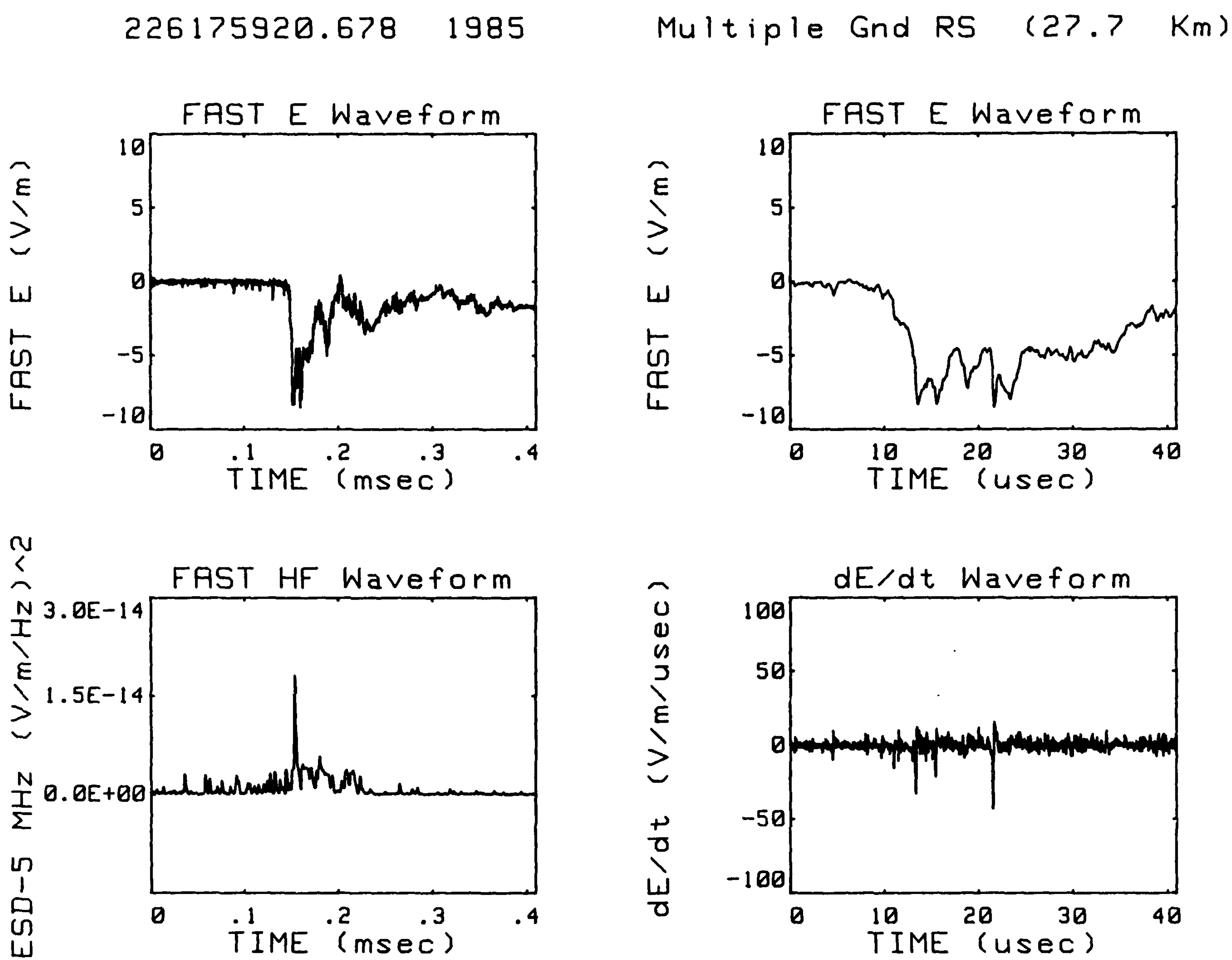
226175901.281   1985   1st RS   (24.6 Km)

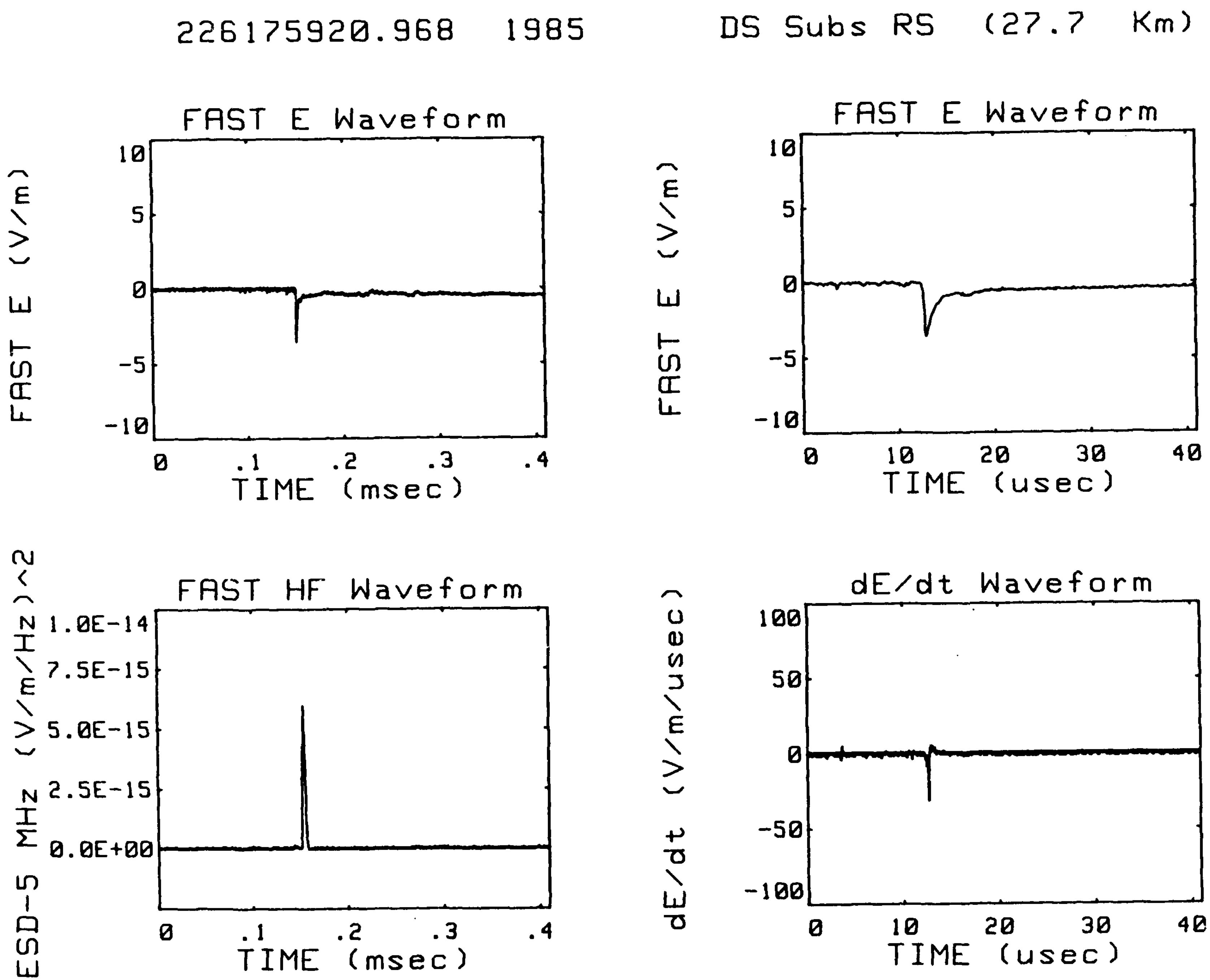


17:59:00.890 14 Aug 1985 (24.6 Km)

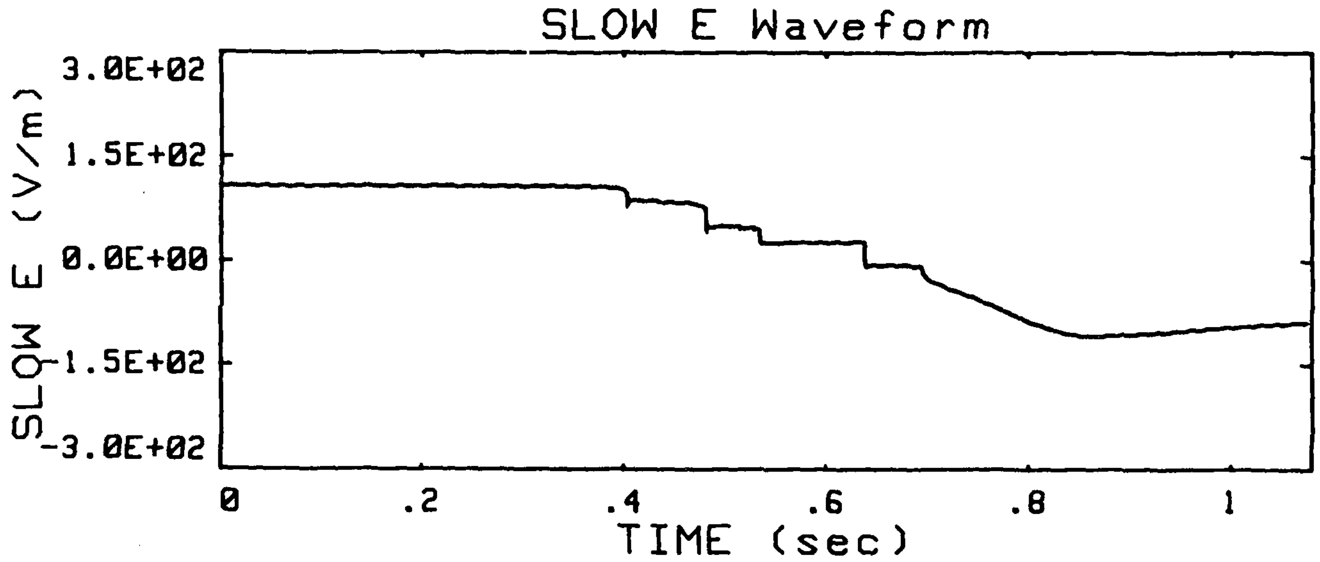


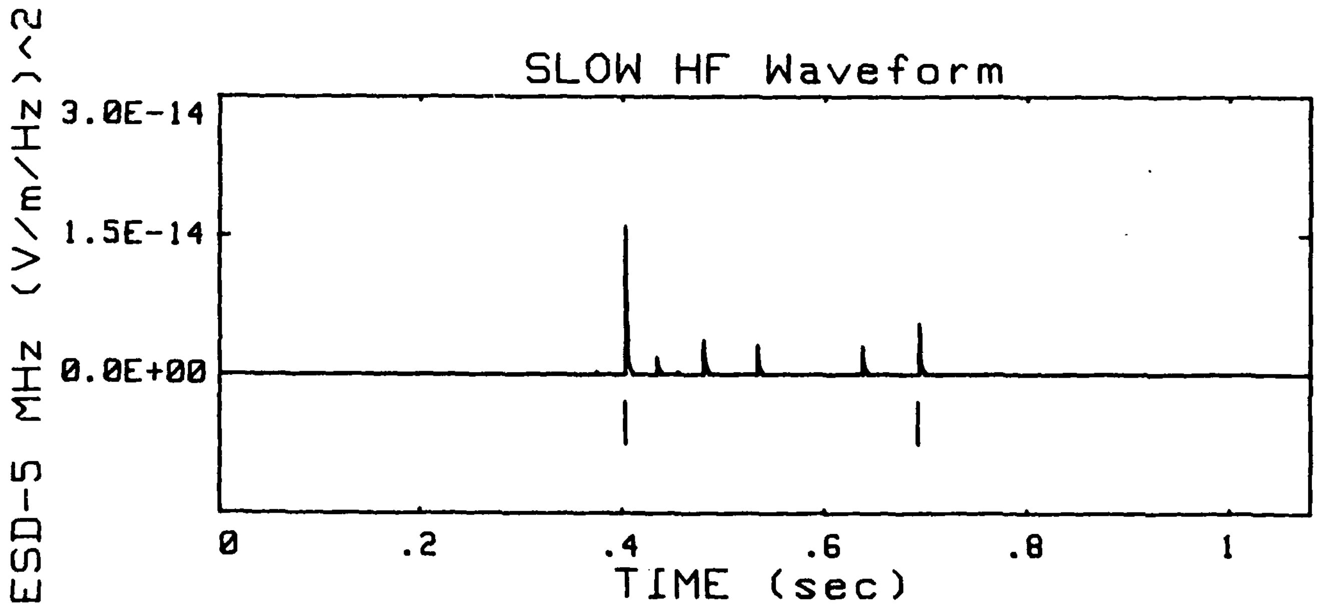



226175920.678 1985
Multiple Gnd RS (27.7 Km)
FAST E Waveform
FAST E (V/m)
10
5
0
-5
-10
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
10
5
0
-5
-10
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
3.0E-14
1.5E-14
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
100
50
0
-50
-100
0
10
20
30
40
TIME (usec)

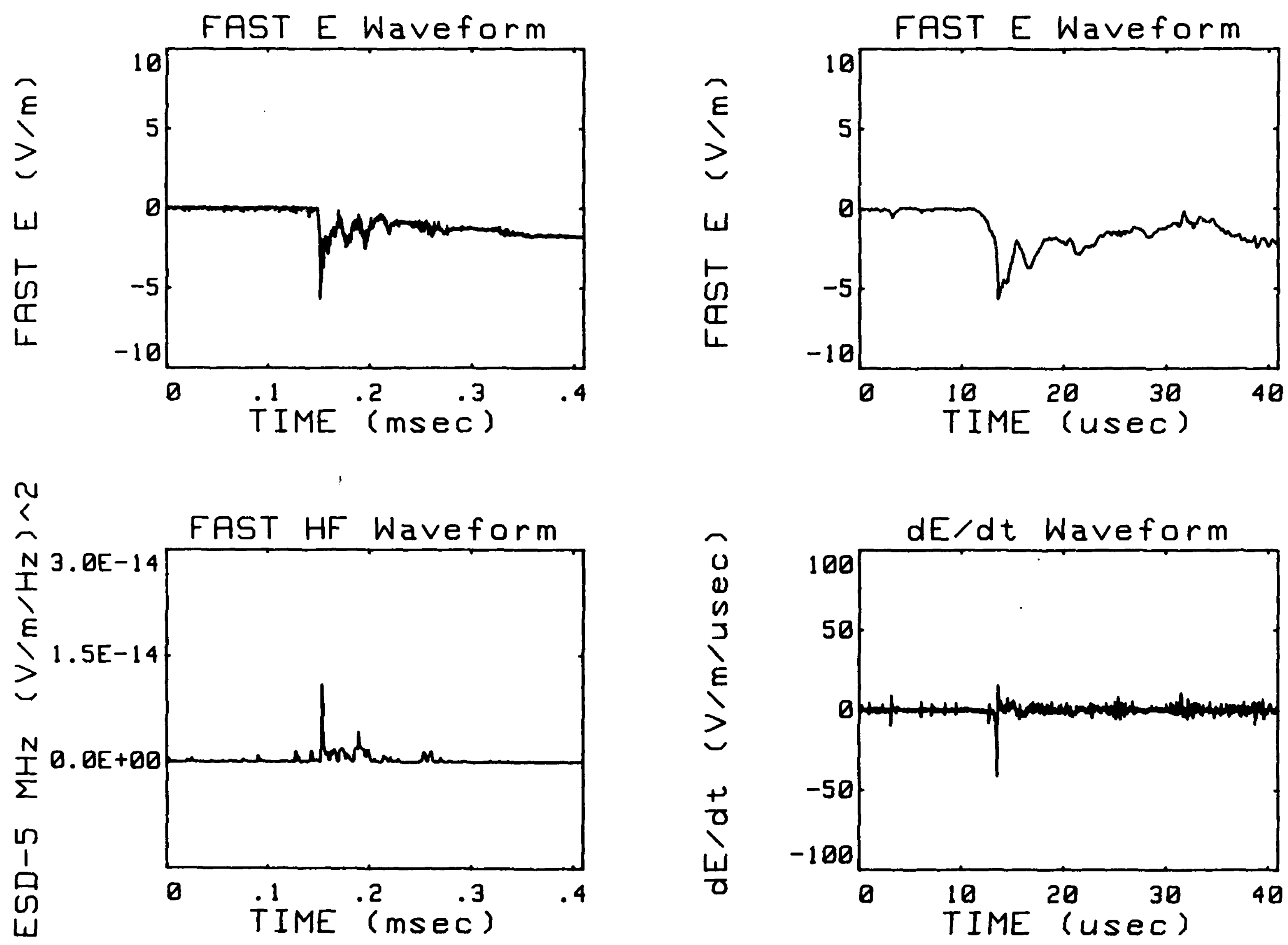

226175920.968 1985
DS Subs RS (27.7 Km)
FAST E Waveform
FAST E (V/m)
10
5
0
-5
-10
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
10
5
0
-5
-10
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
1.0E-14
7.5E-15
5.0E-15
2.5E-15
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
100
50
0
-50
-100
0
10
20
30
40
TIME (usec)

17:59:20.288 14 Aug 1985 (27.7 Km)

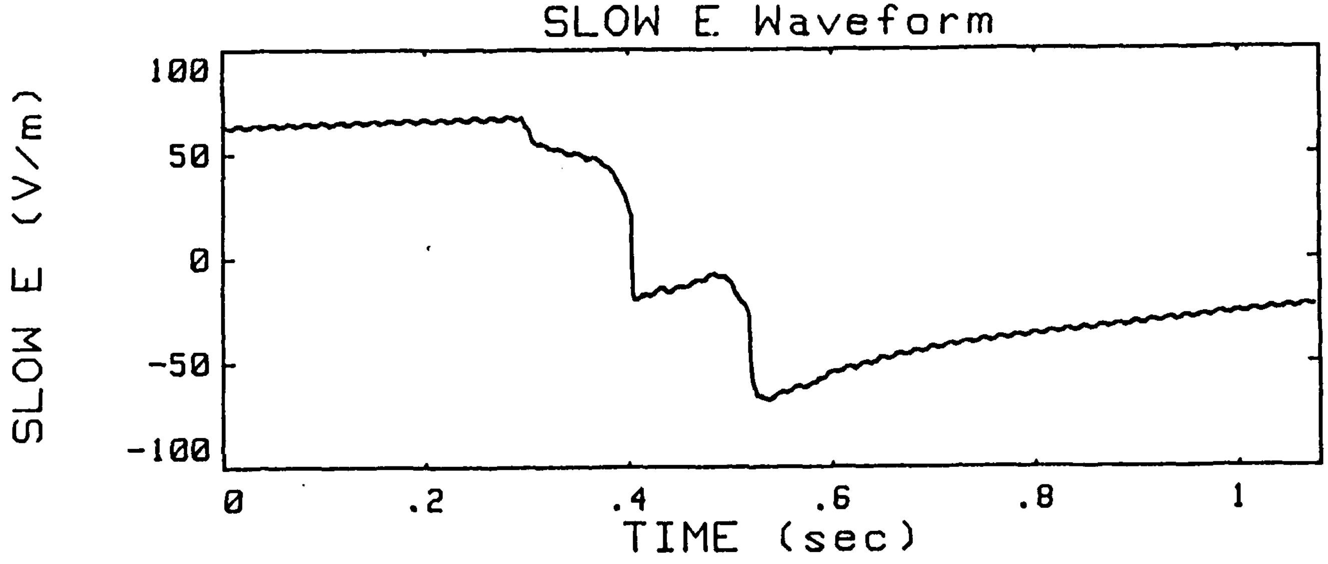


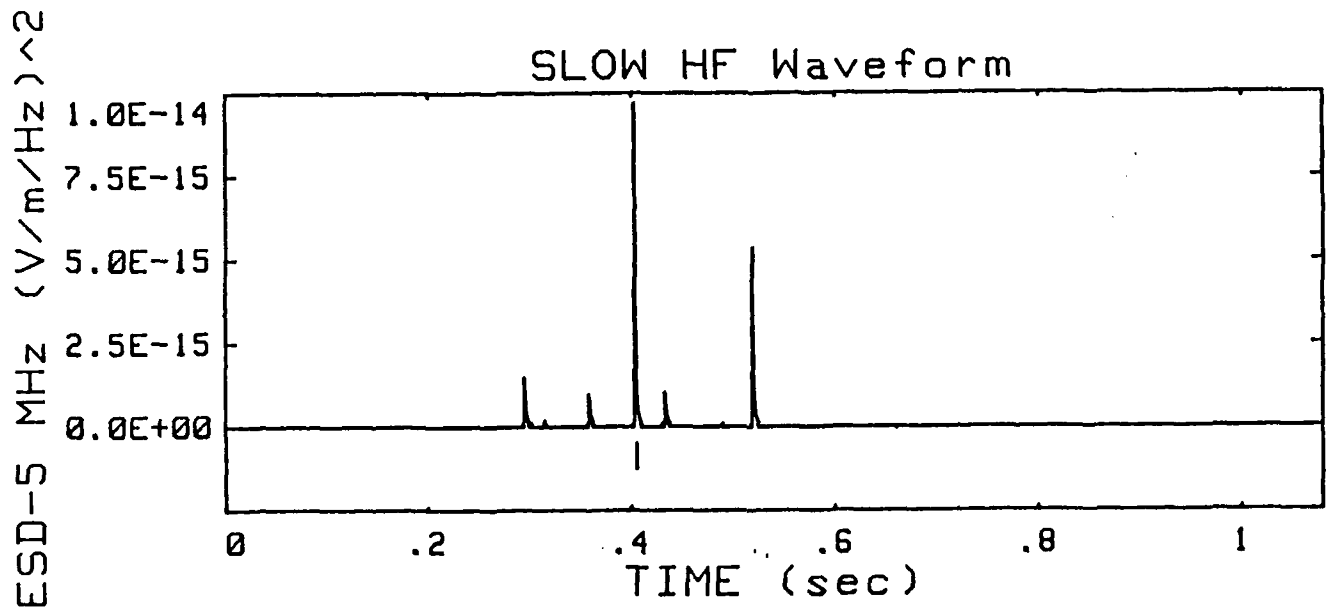


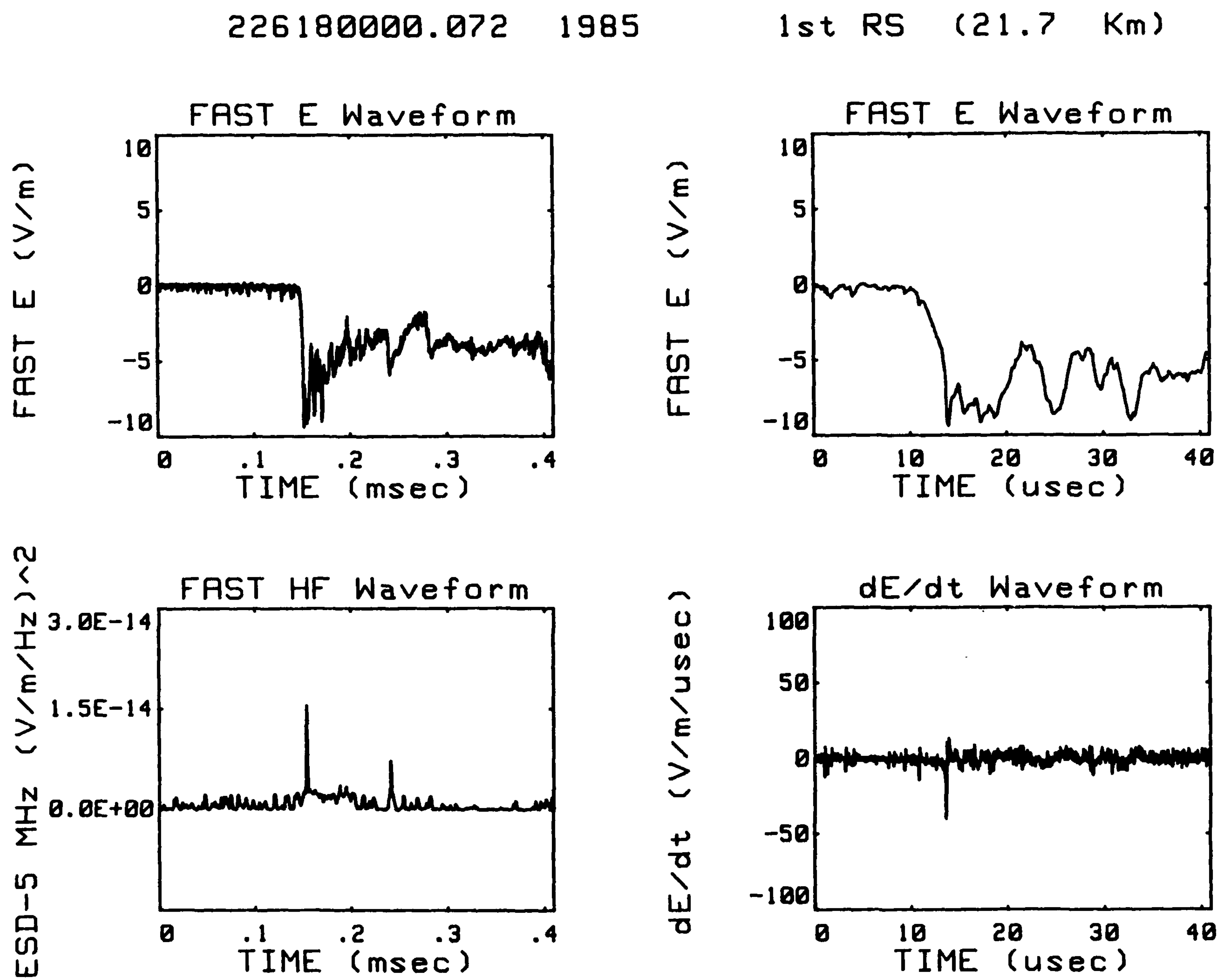
226175926.290 1985 1st RS (18.8 Km)



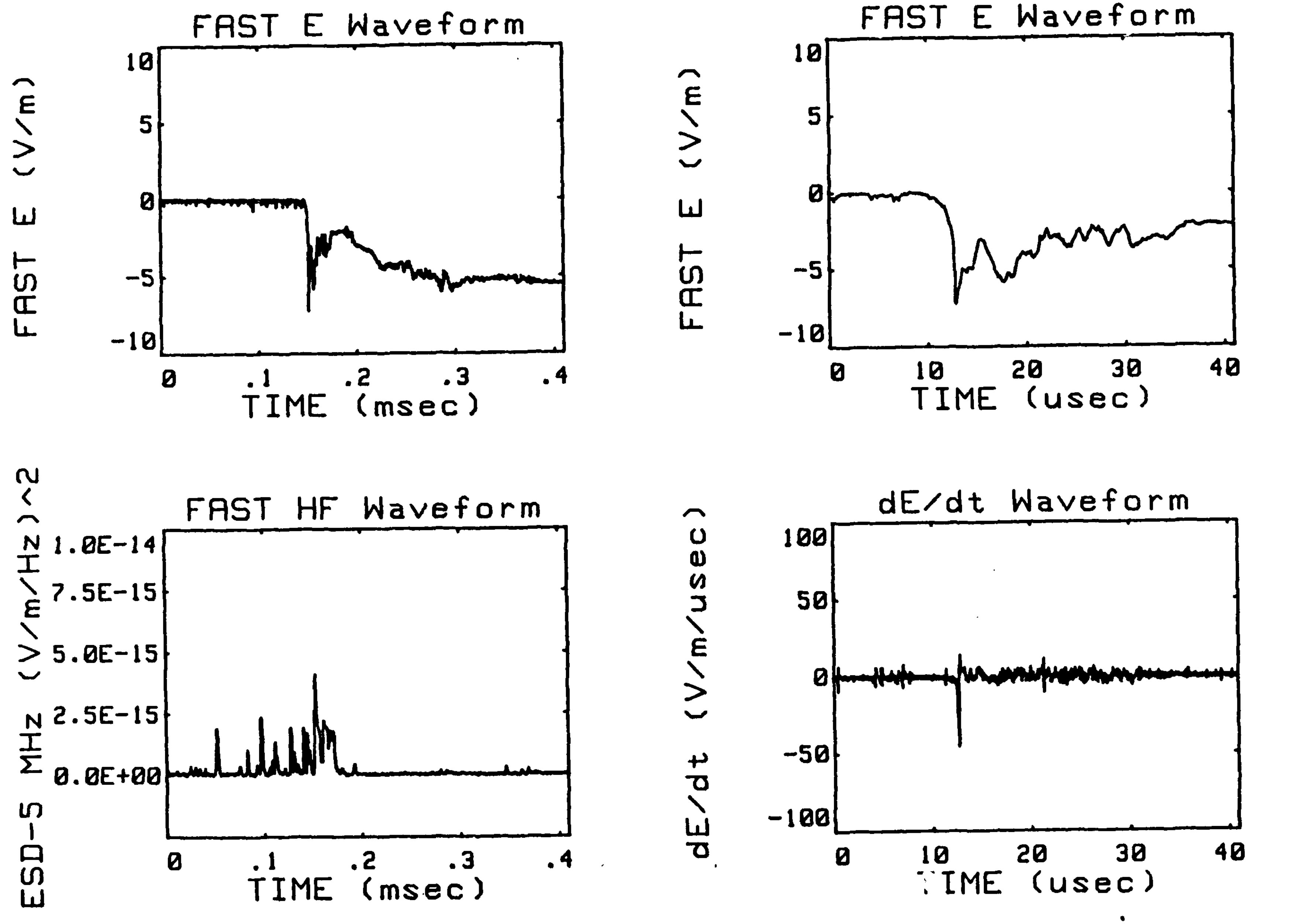
17:59:25.898 14 Aug 1985 (18.8 Km)






226180000.072 1985 1st RS (21.7 Km)
FAST E Waveform
FAST E (V/m)
10
5
0
-5
-10
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
10
5
0
-5
-10
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
3.0E-14
1.5E-14
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
100
50
0
-50
-100
0
10
20
30
40
TIME (usec)

226180000.175 1985 Anomalous #1 RS (21.7 Km)



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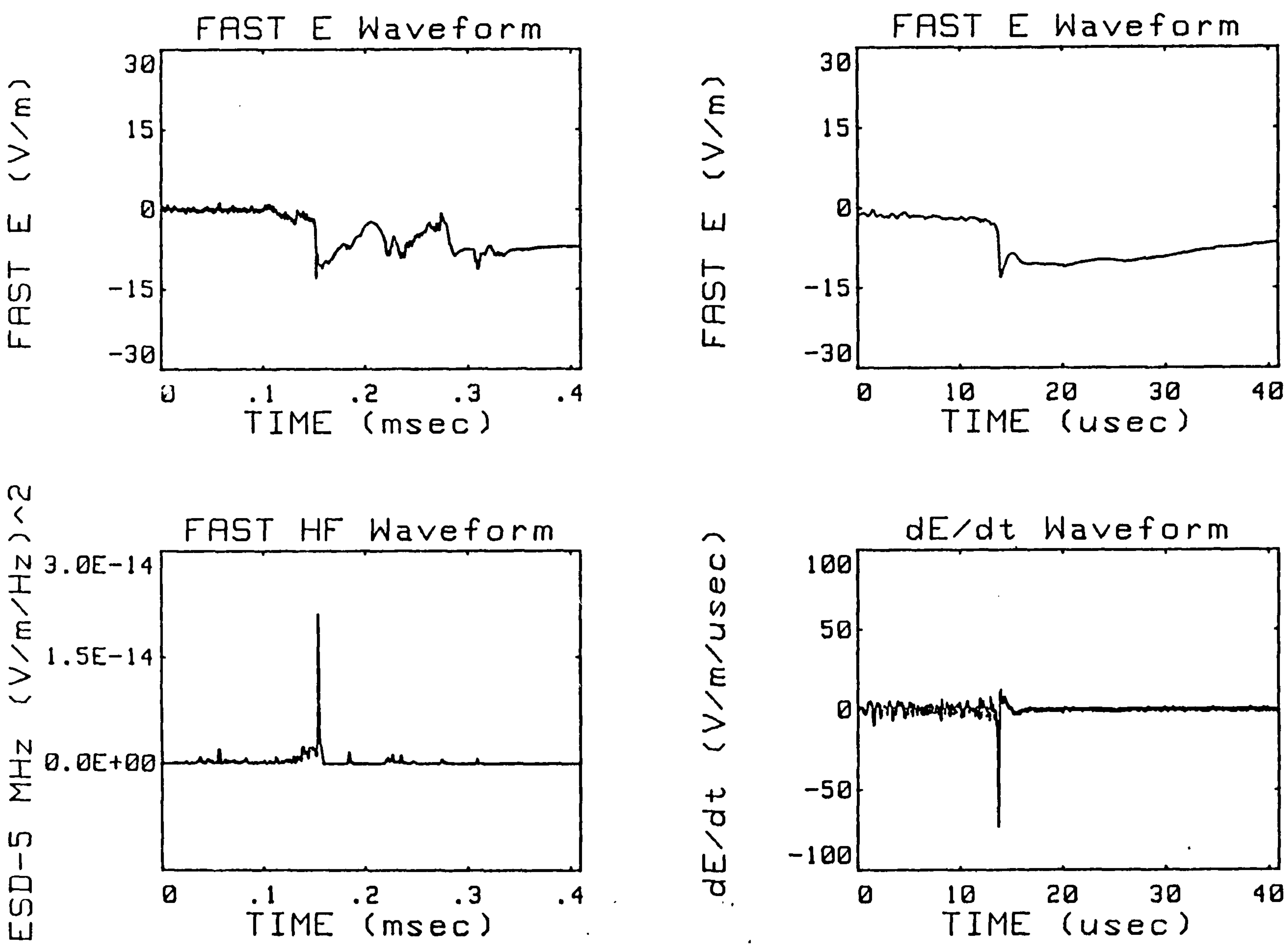
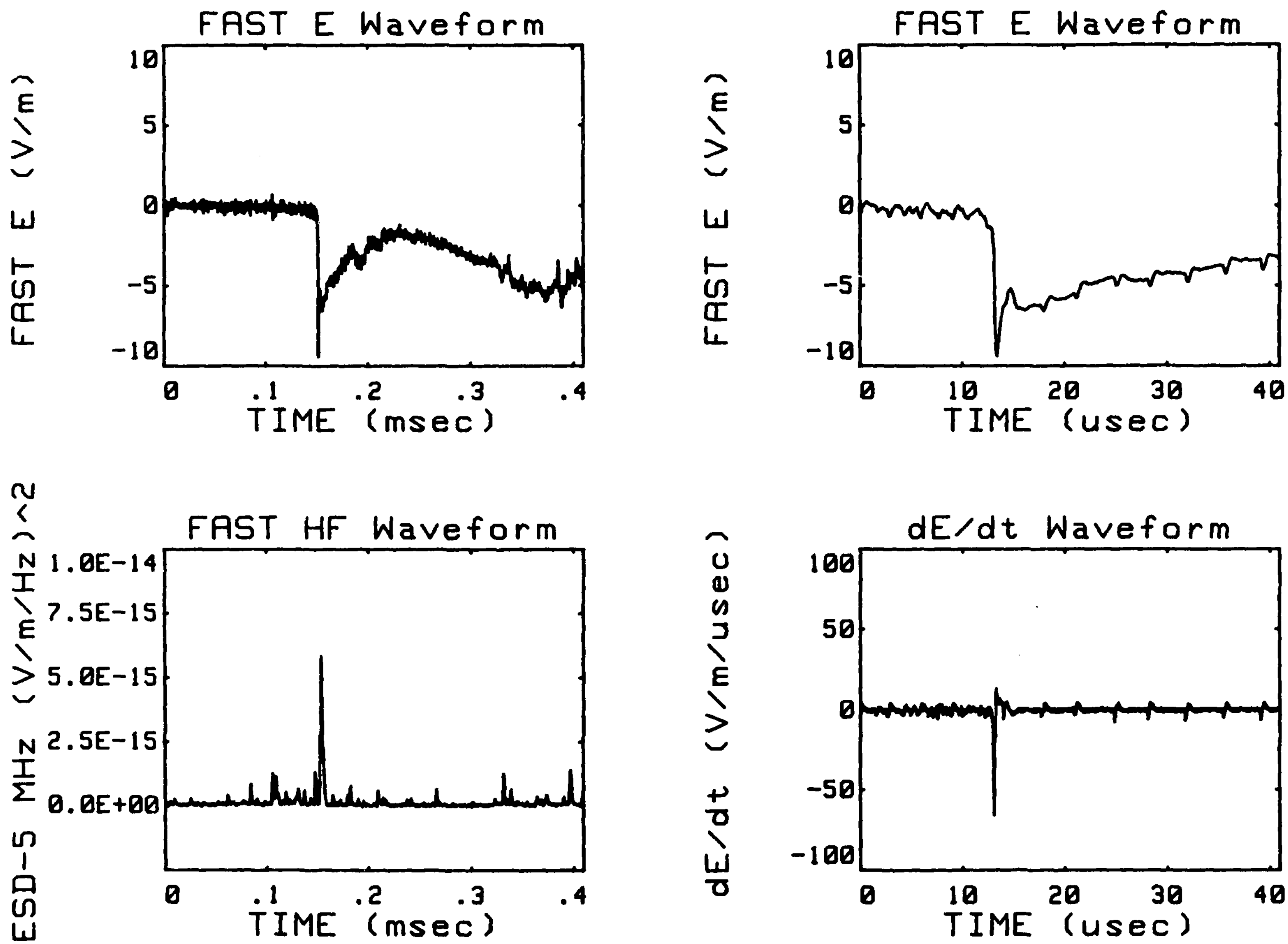
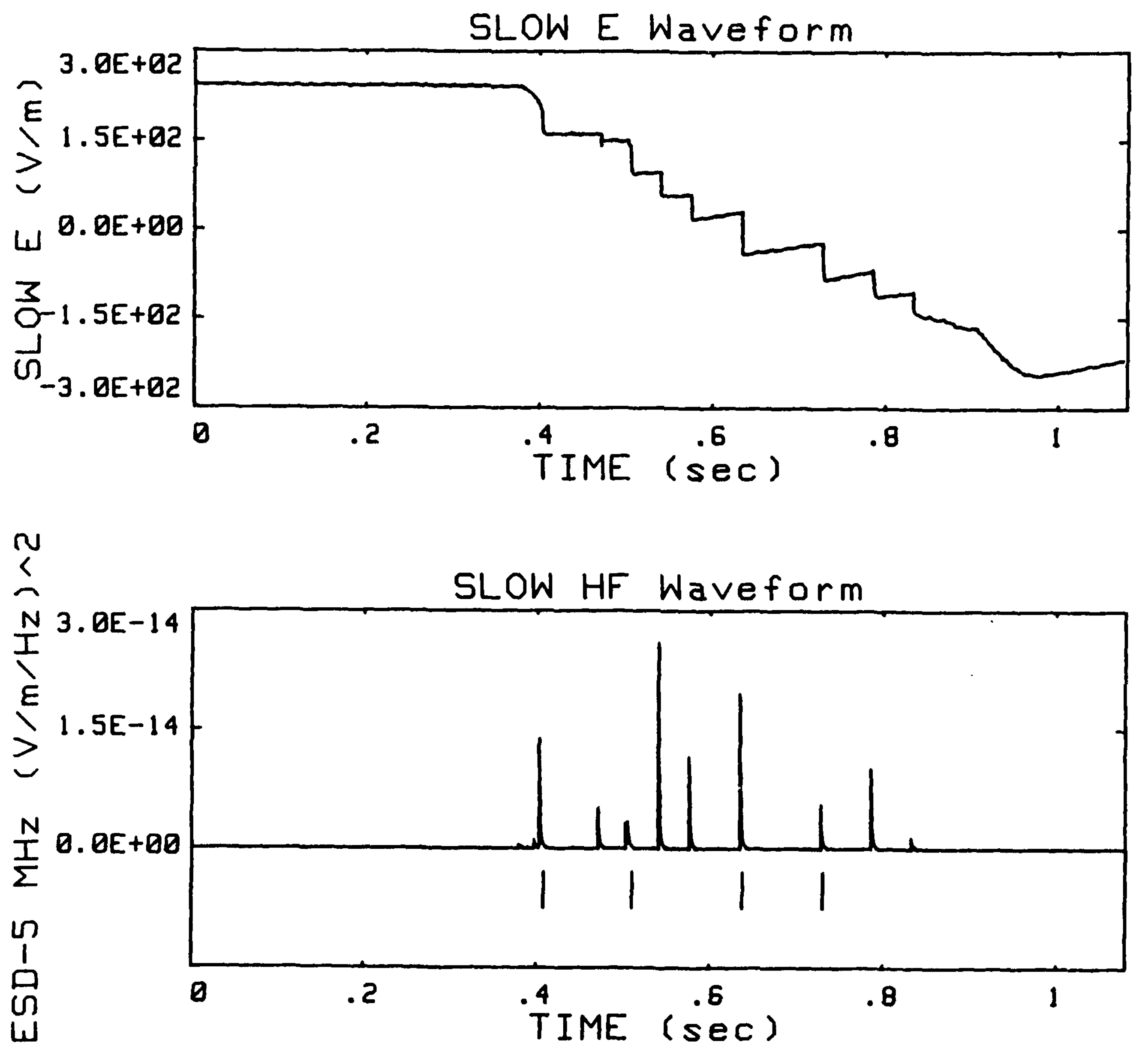
226180000.303 1985 Chaotic Subs RS (21.7 Km)



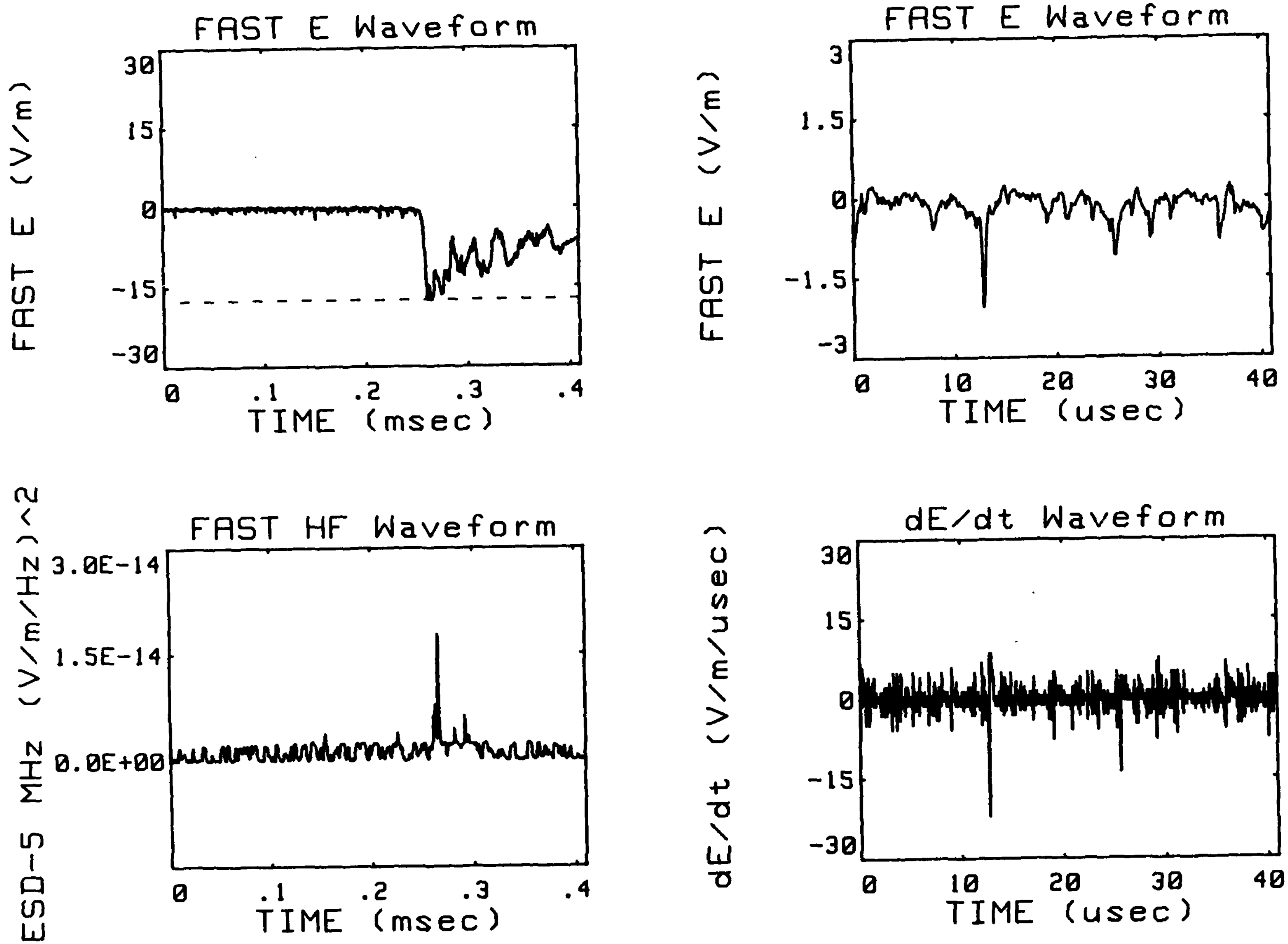
226180000.396 1985 DS Subs RS (21.7 Km)



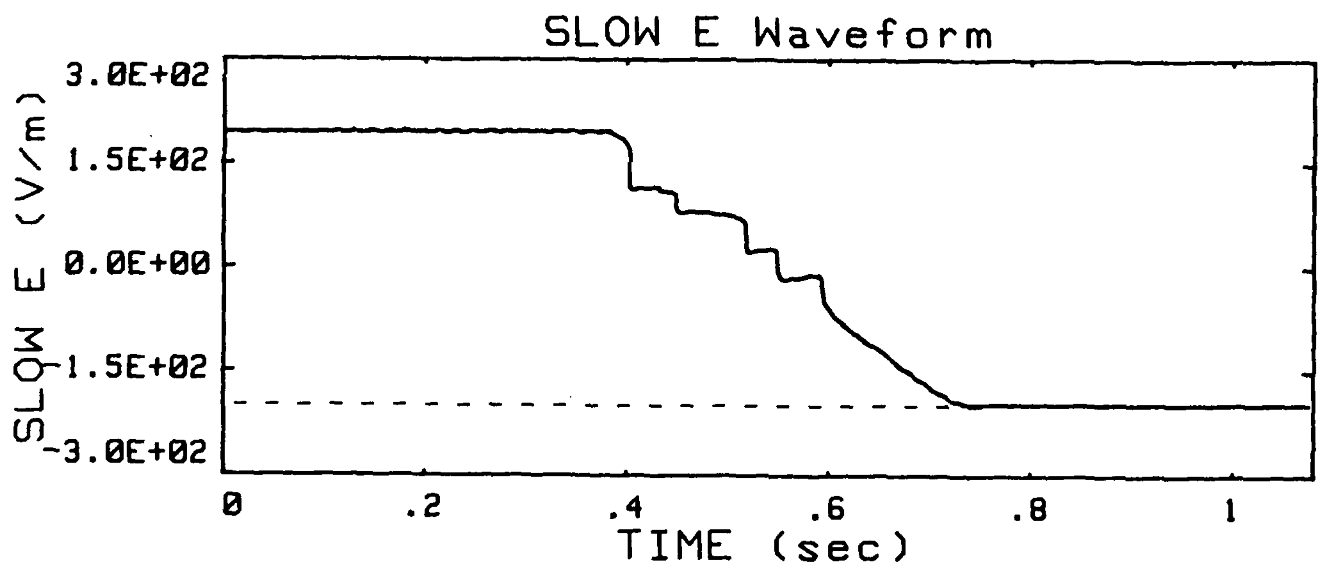
17:59:59.677 14 Aug 1985 (21.7 Km)

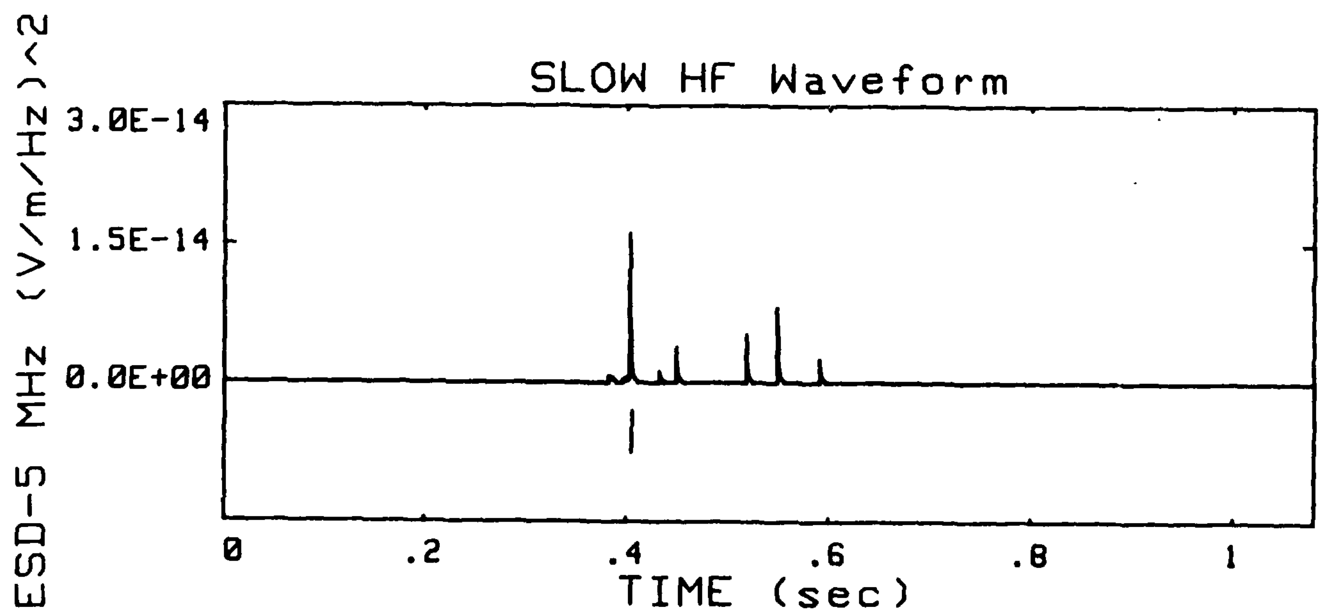


226180056.680 1985 Stepped Leader (21.8 Km)

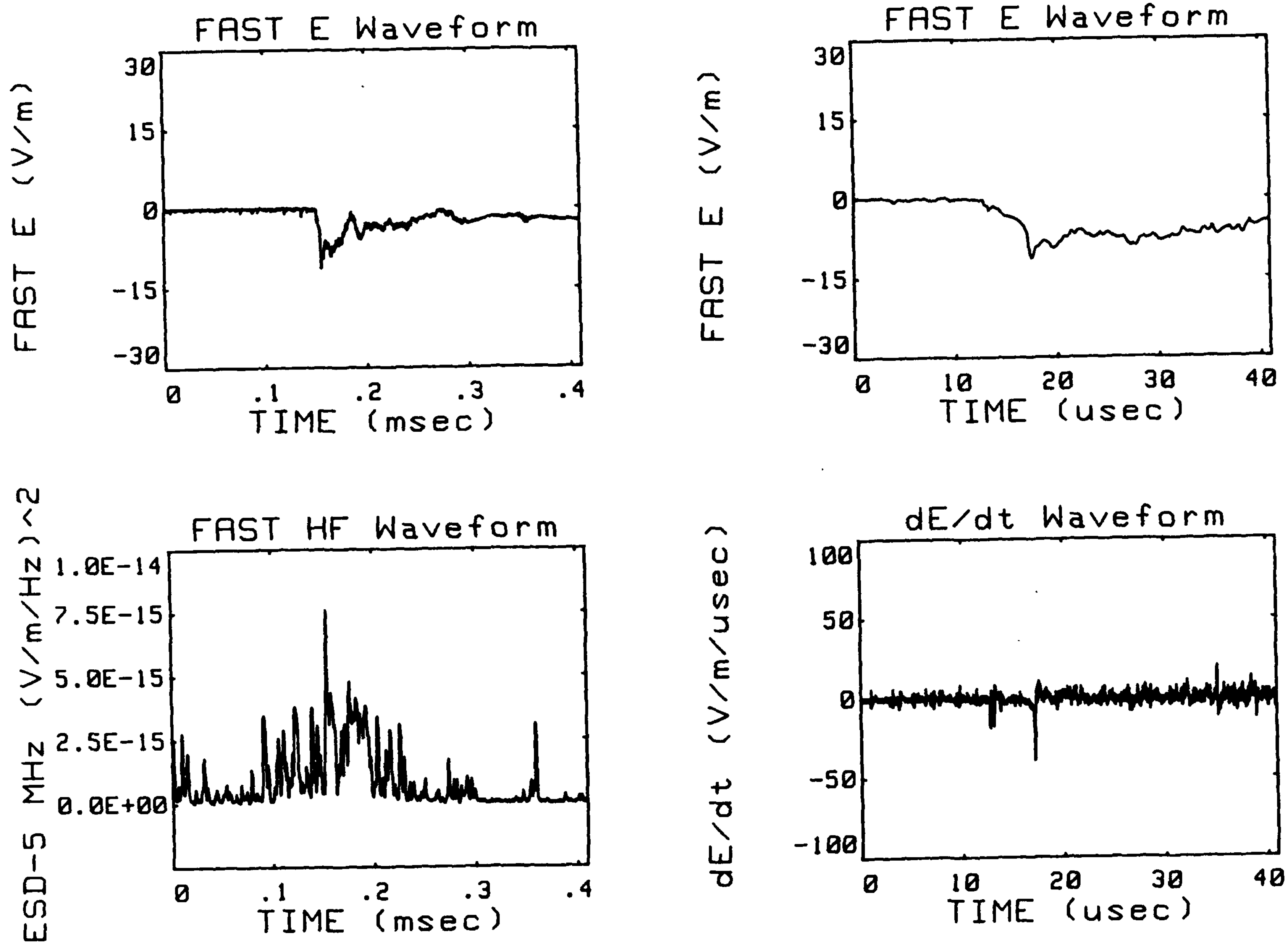


18:00:56.288 14 Aug 1985 (21.8 Km)

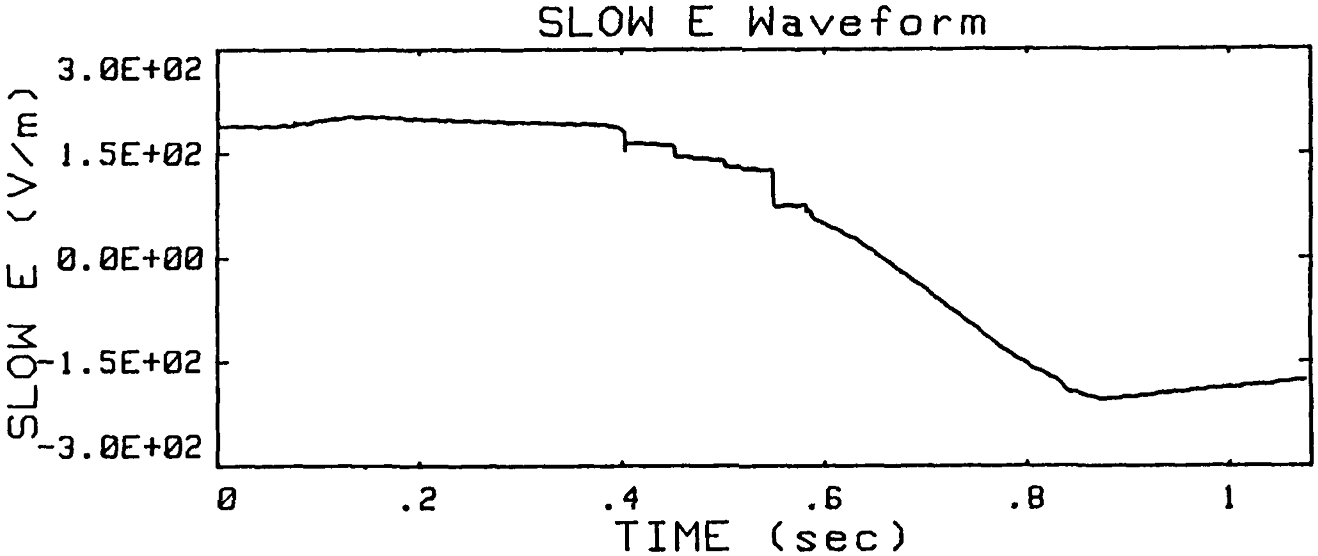


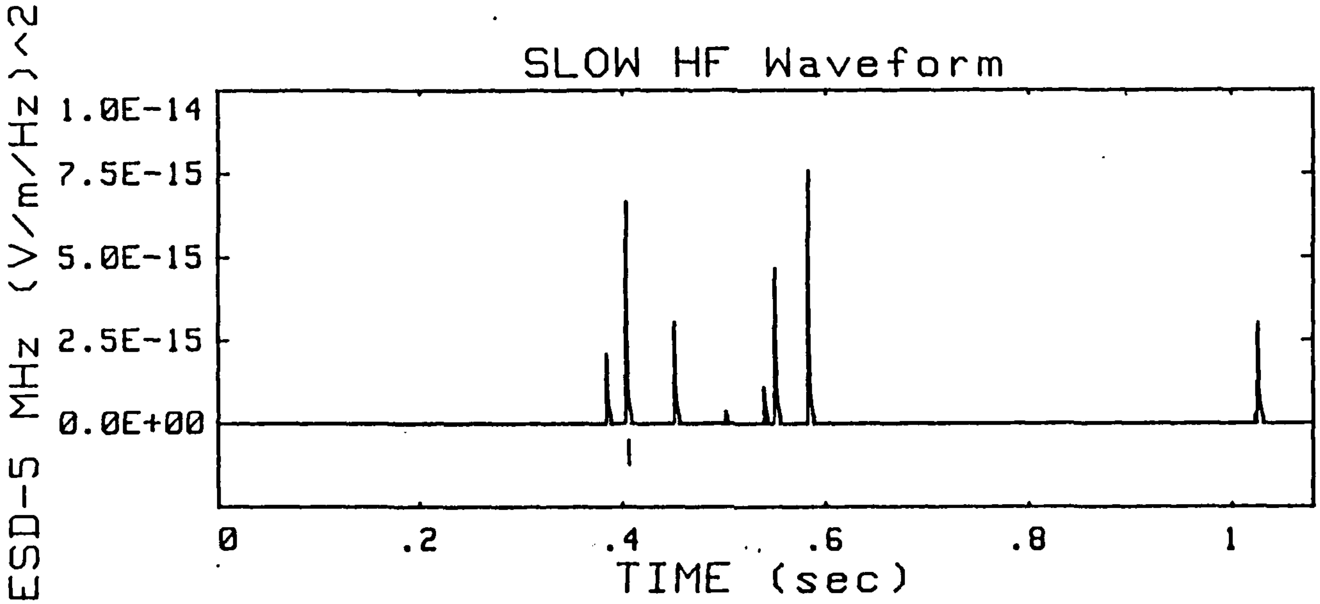


226180152.034 1985 1st RS (27.2 Km)

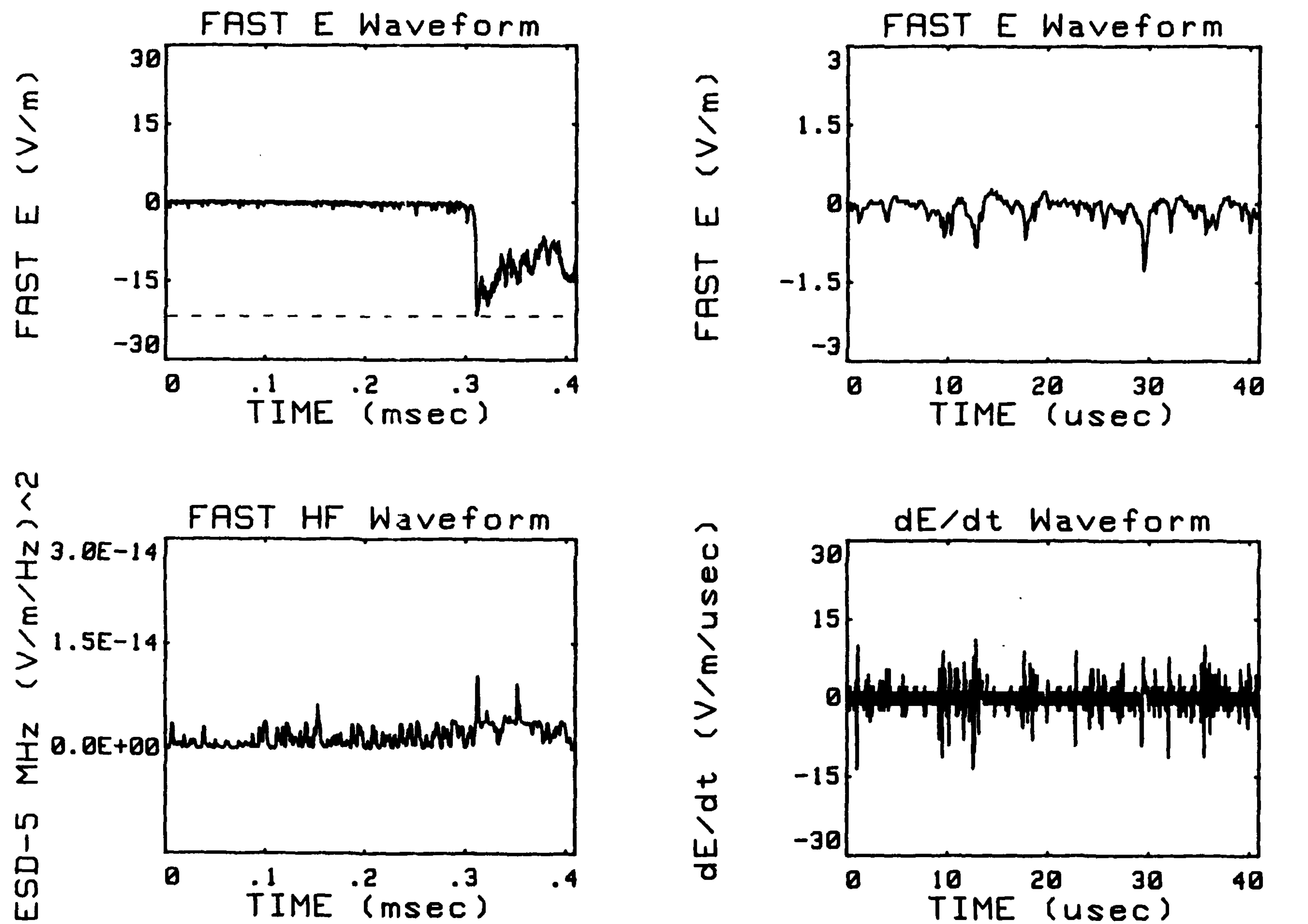


18:01:51.641 14 Aug 1985 (27.2 Km)

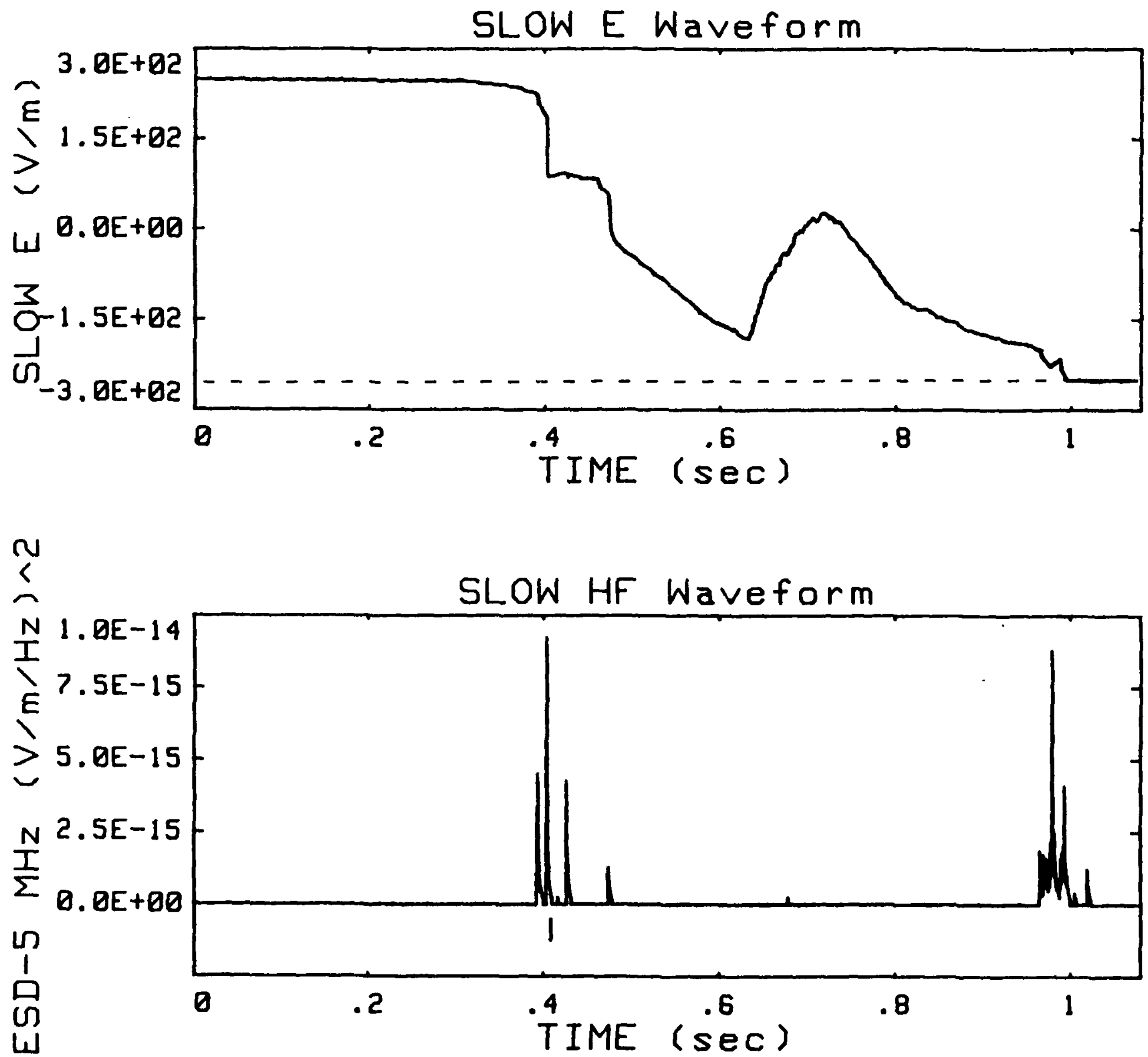




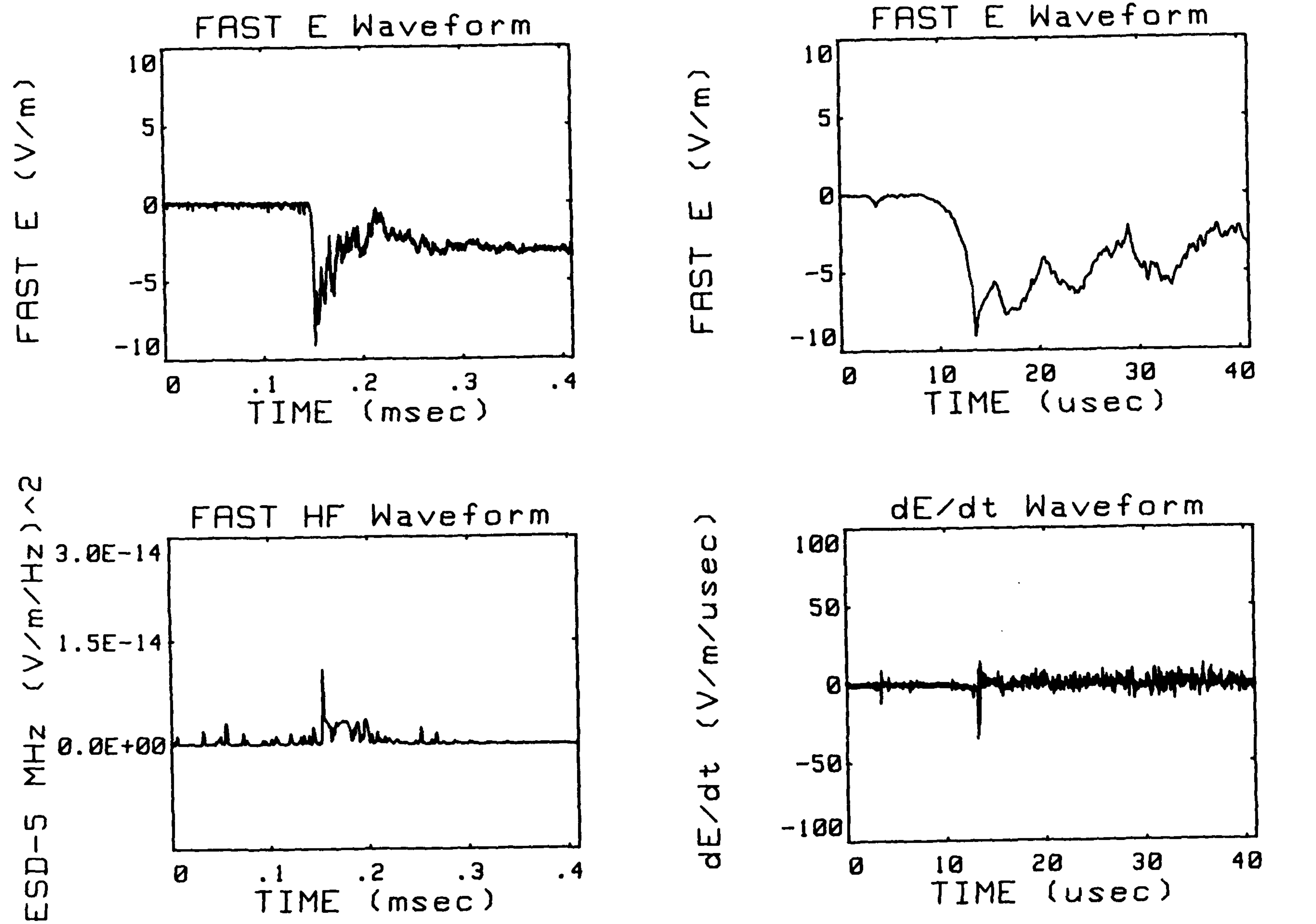
226180441.221 1985 Stepped Leader (27.0 Km)



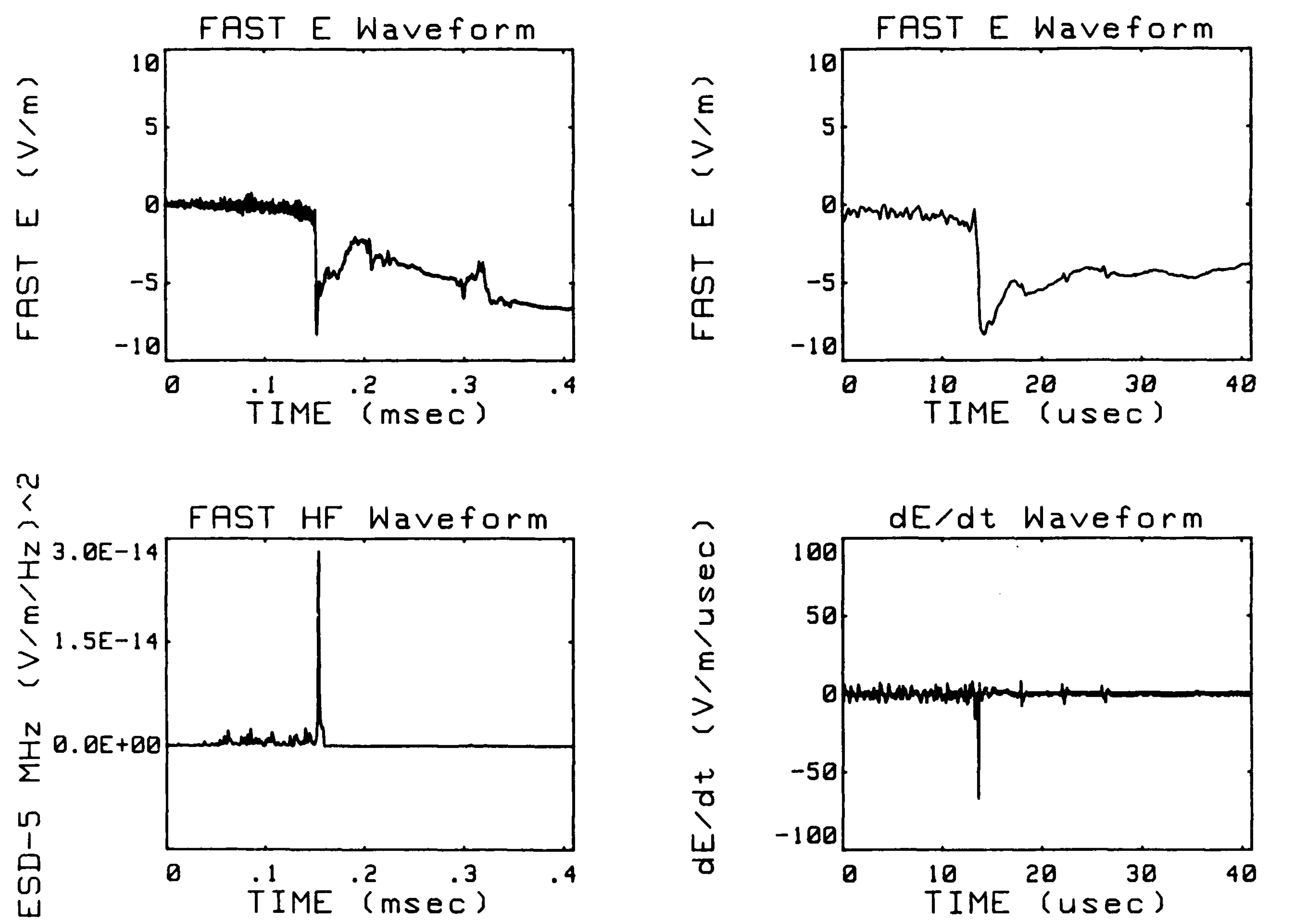
18:04:40.826 14 Aug 1985 (27.0 Km)



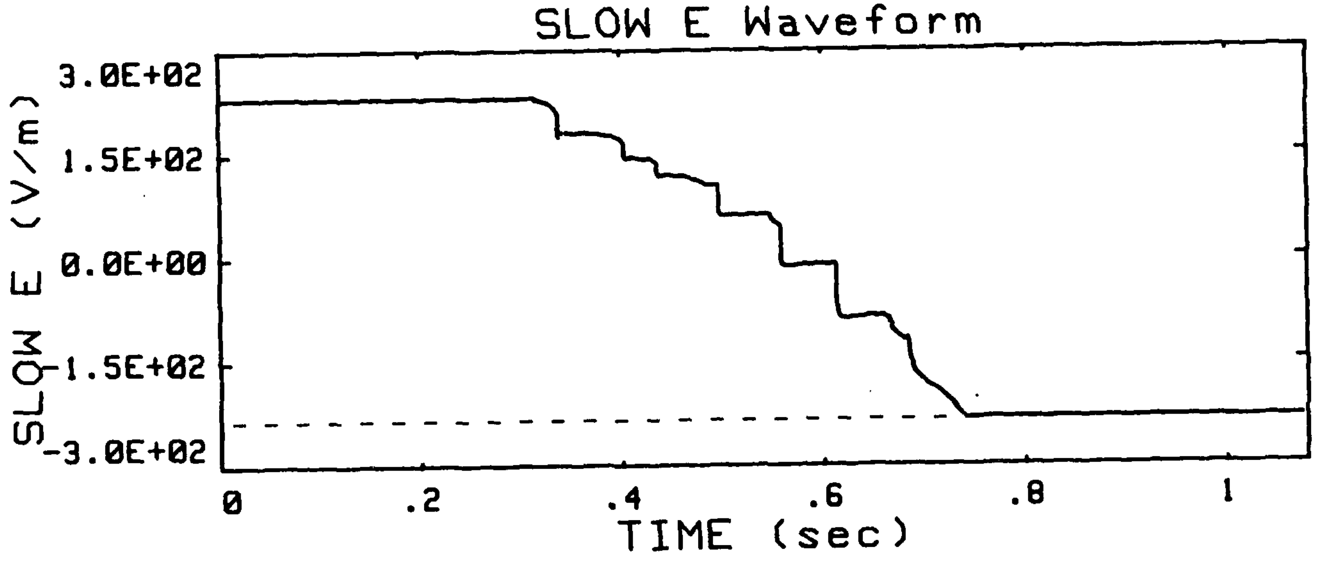
226180544.237   1985   1st RS   (25.3 Km)

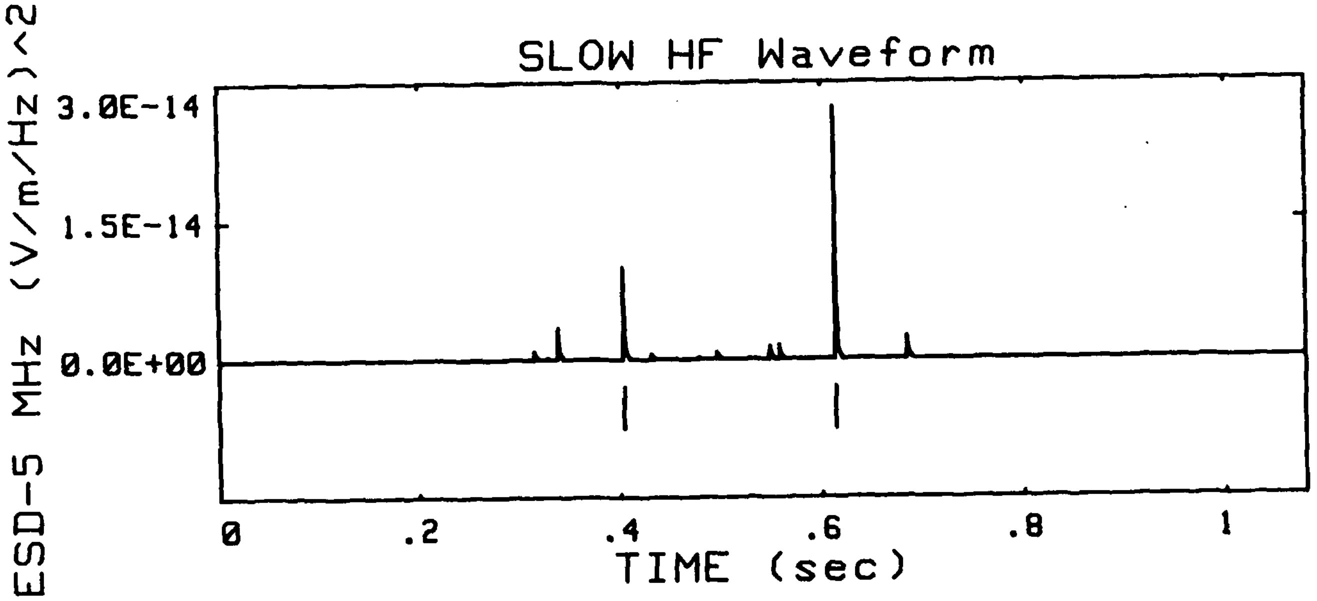


226180544.448 1985 Chaotic Subs RS (25.3 Km)

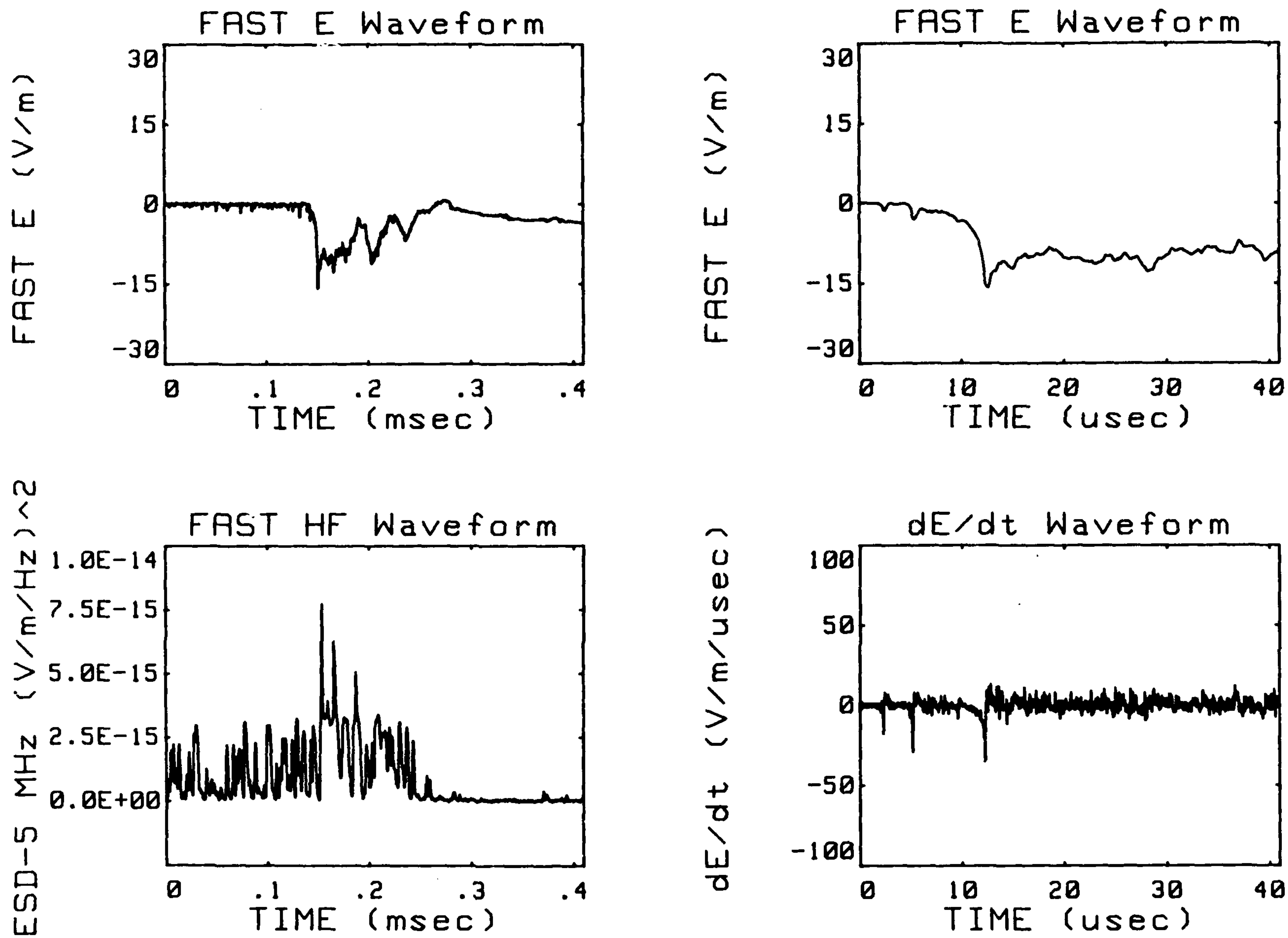


18:05:43.846 14 Aug 1985 (25.3 Km)

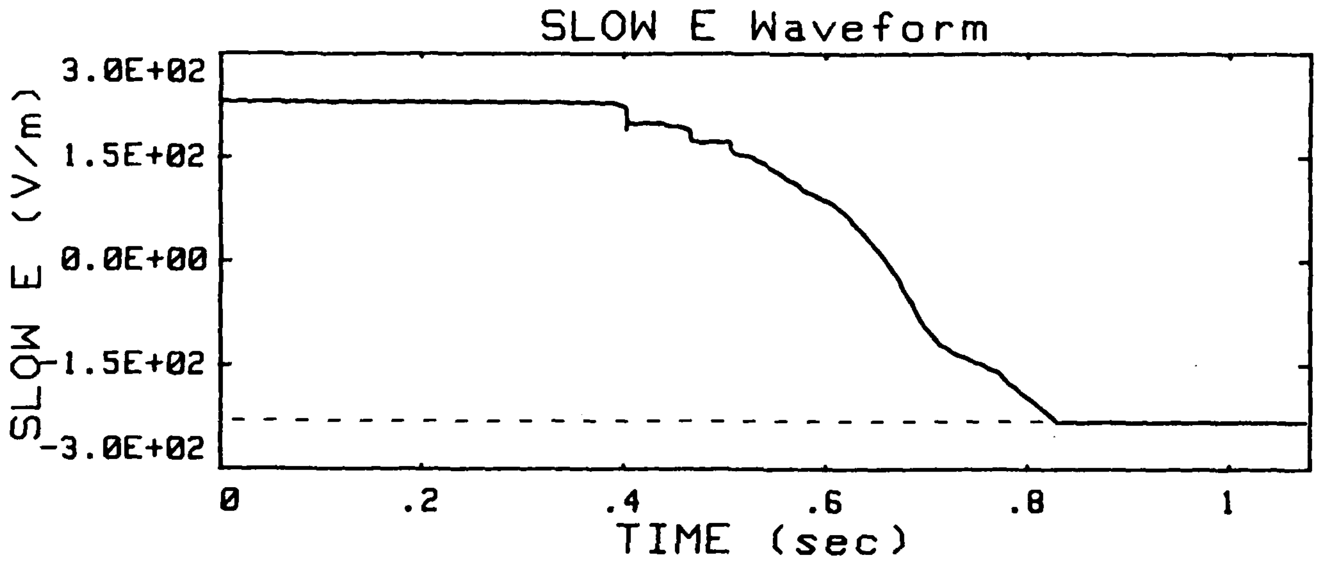


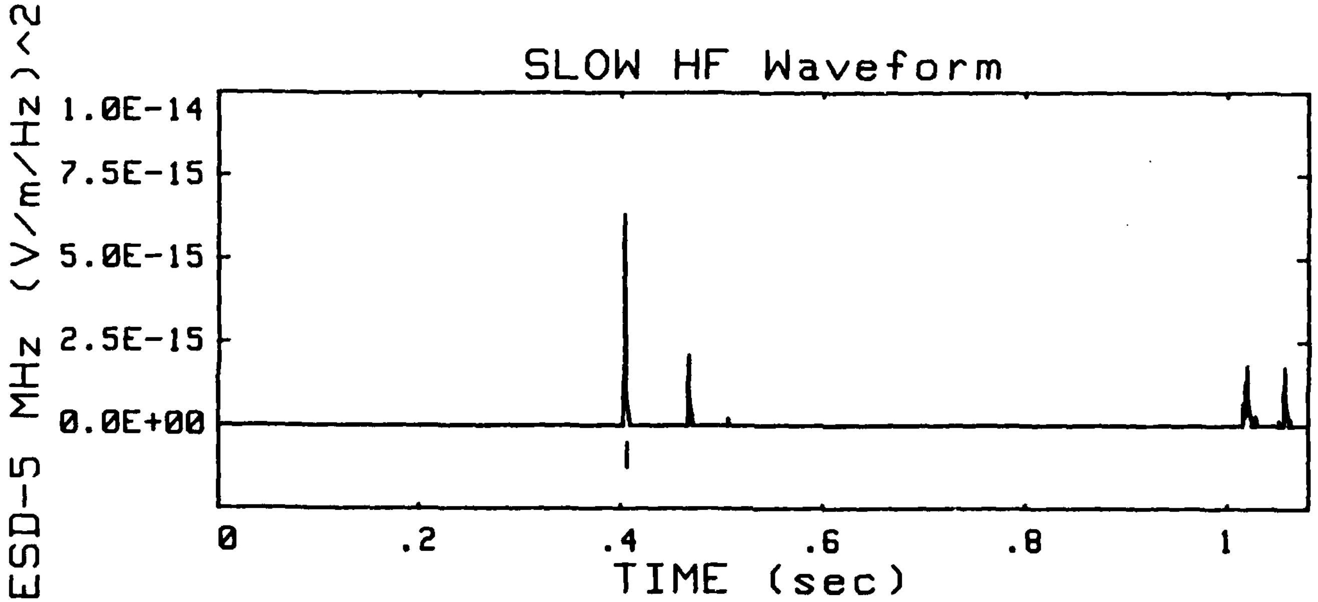


226180631.715 1985 1st RS (24.8 Km)

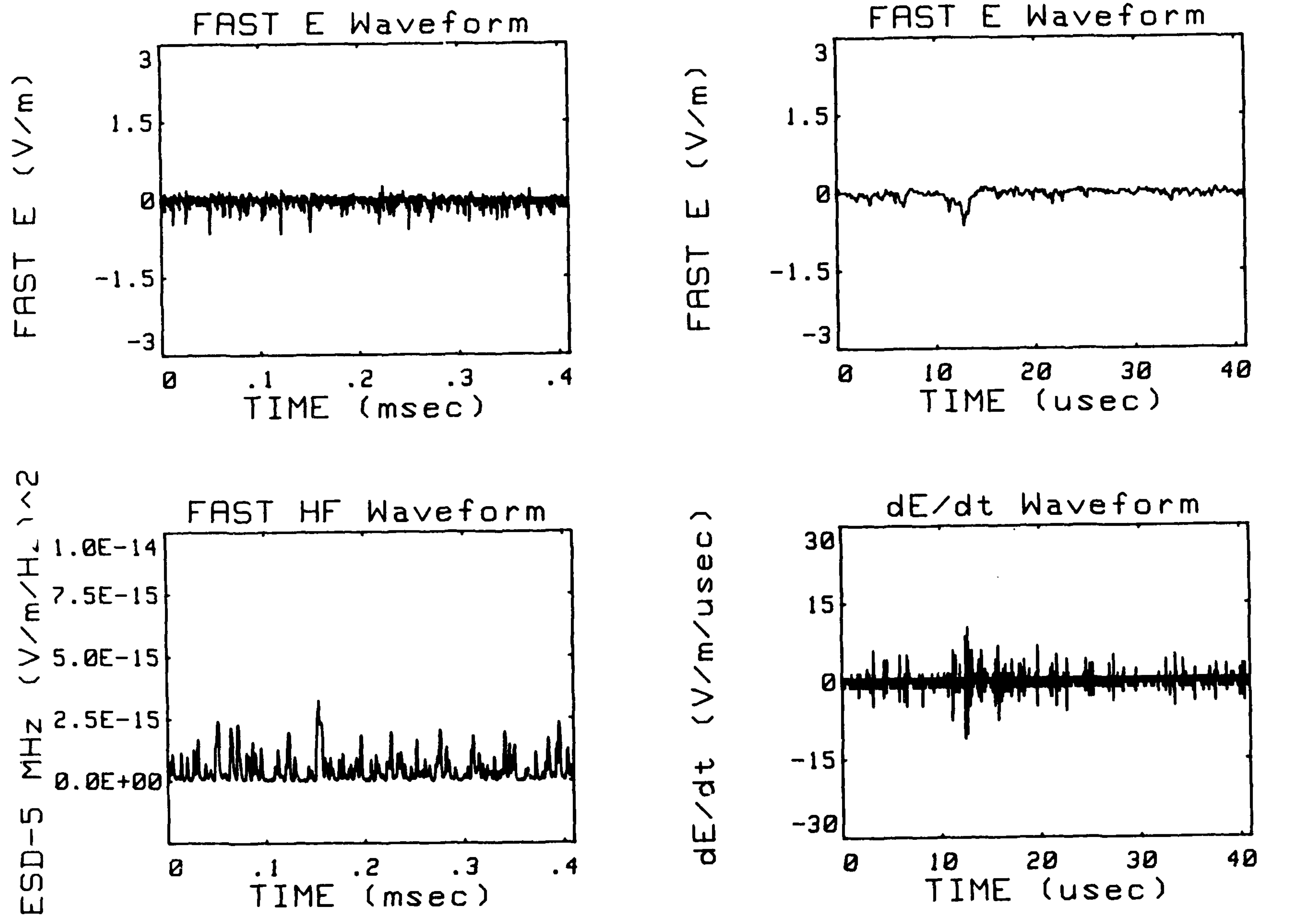


18:06:31.322 14 Aug 1985 (24.8 Km)

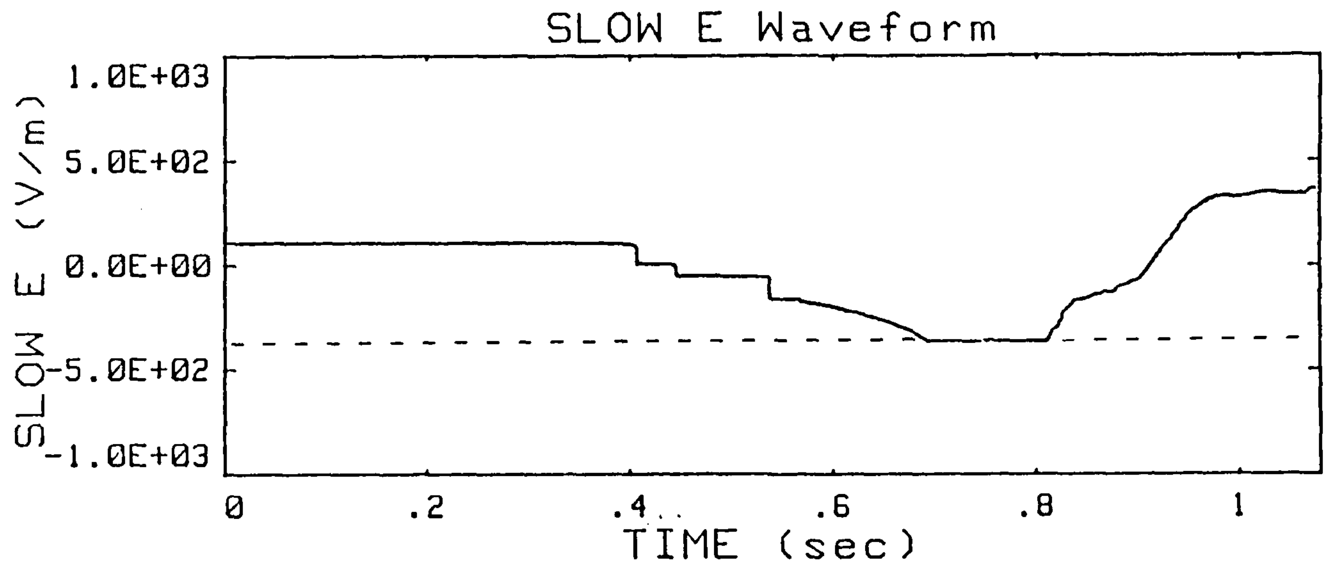


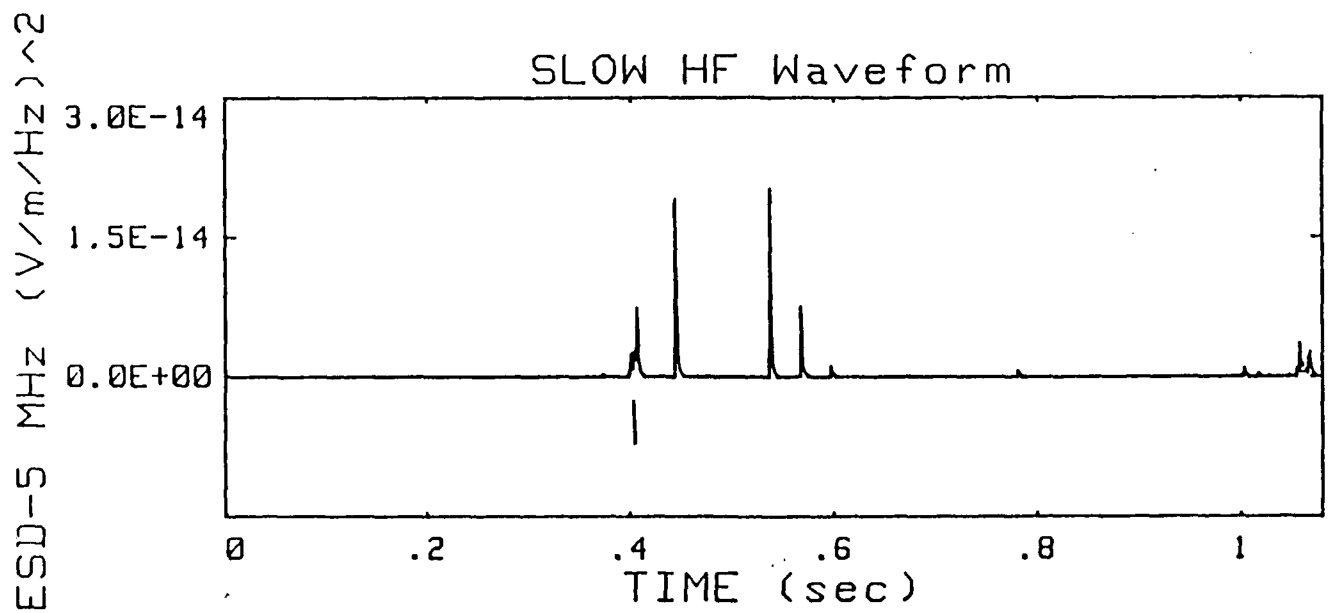


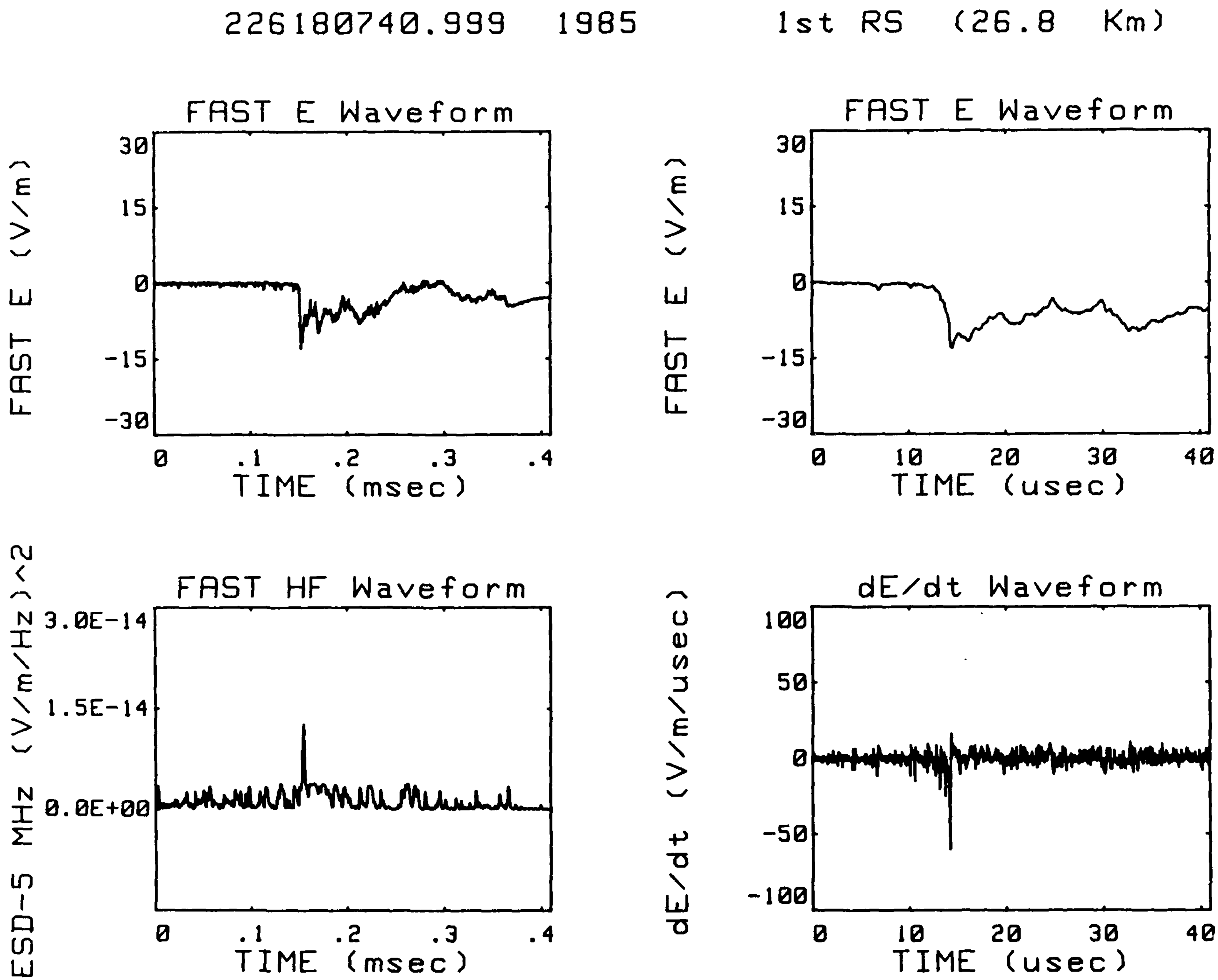
226180701.818 1985 Char Cloud Pulse (21.7 Km)



18:07:01.427 14 Aug 1985 (21.7 Km)

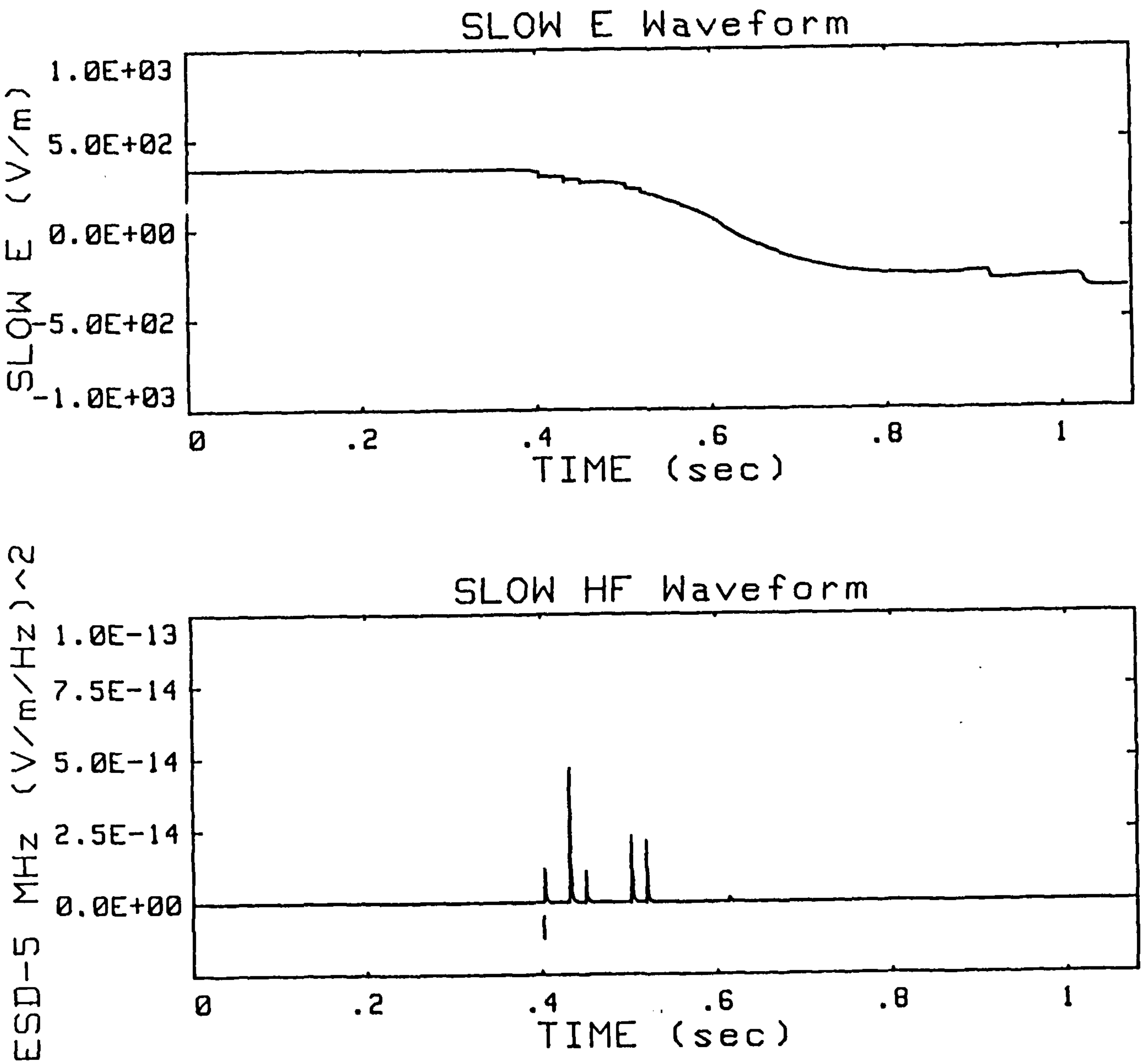




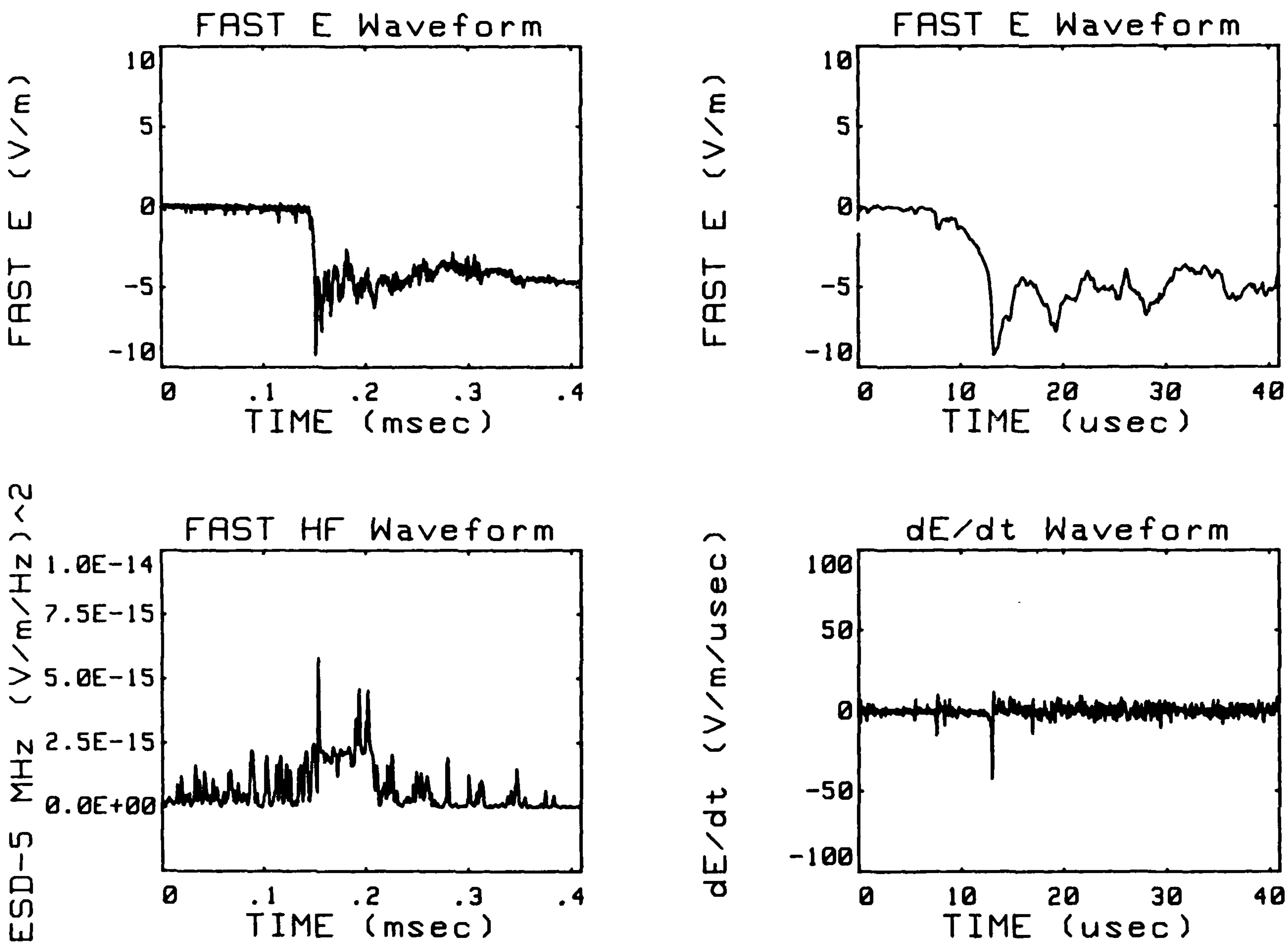


226180740.999 1985 1st RS (26.8 Km)
FAST E Waveform
FAST E (V/m)
30
15
0
-15
-30
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
30
15
0
-15
-30
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
3.0E-14
1.5E-14
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
100
50
0
-50
-100
0
10
20
30
40
TIME (usec)

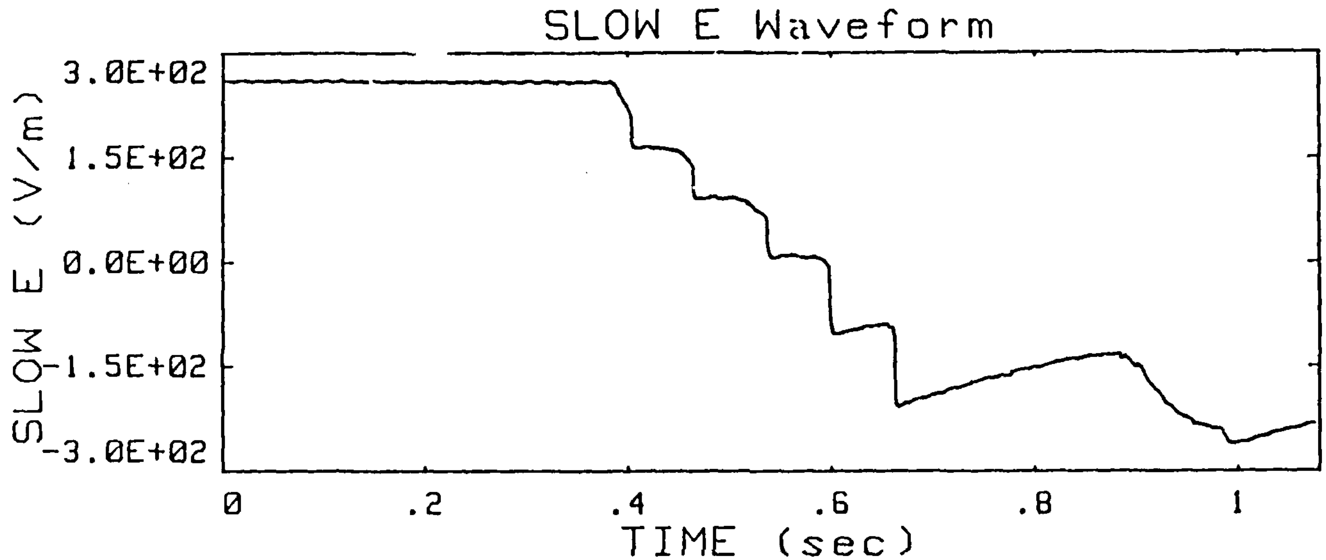
18:07:40.610 14 Aug 1985 (26.8 Km)

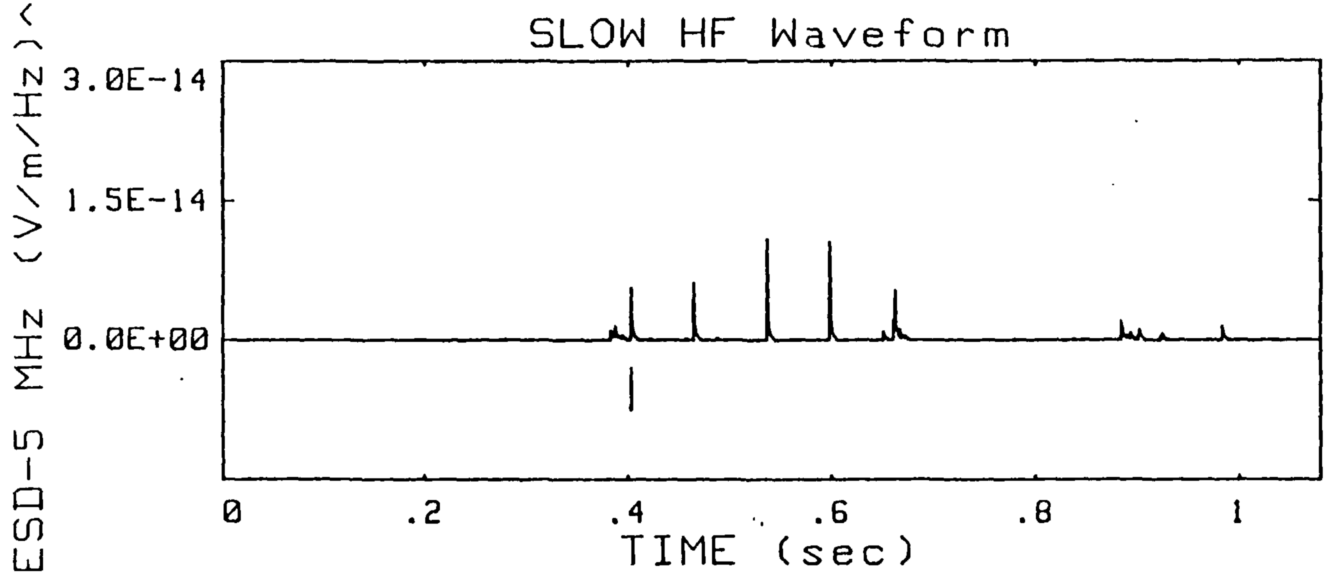


226180806.276 1985 1st RS (20.7 Km)

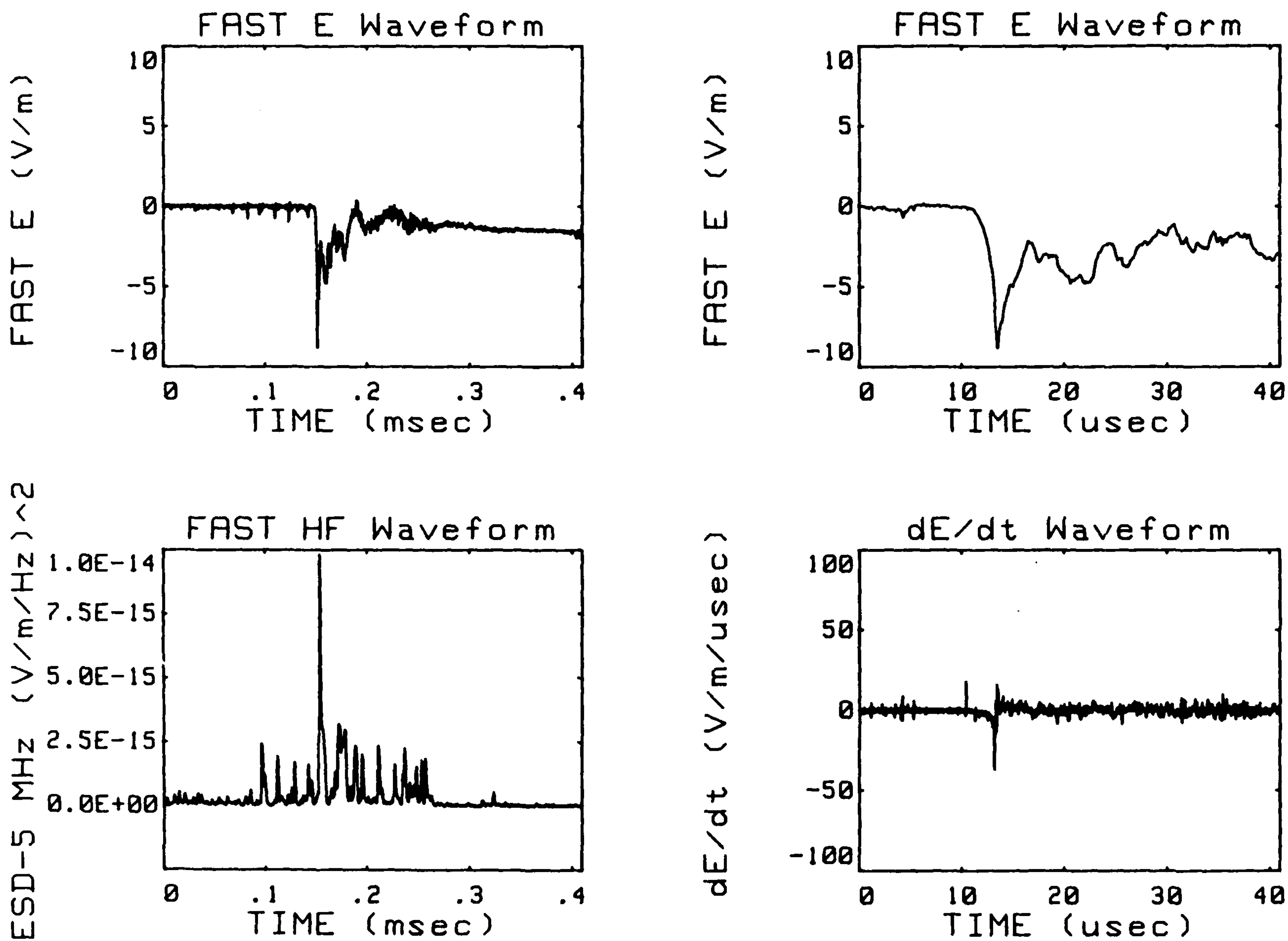


18:08:05.886 14 Aug 1985 (20.7 Km)

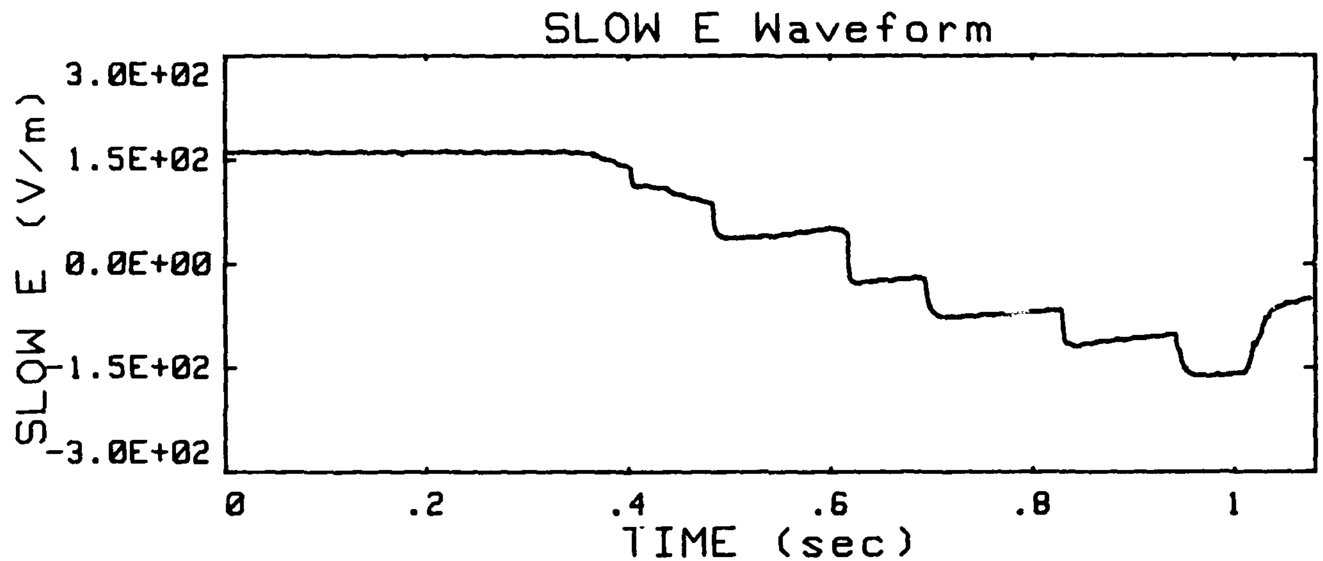


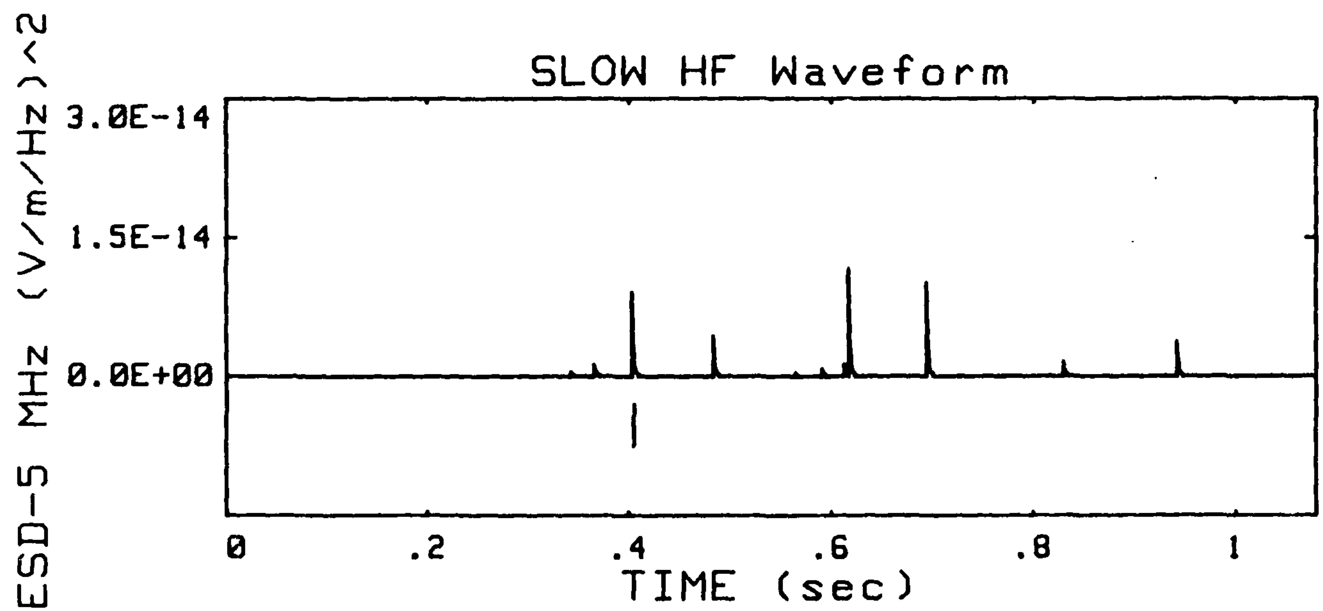


226180819.309 1985 1st RS (24.5 Km)

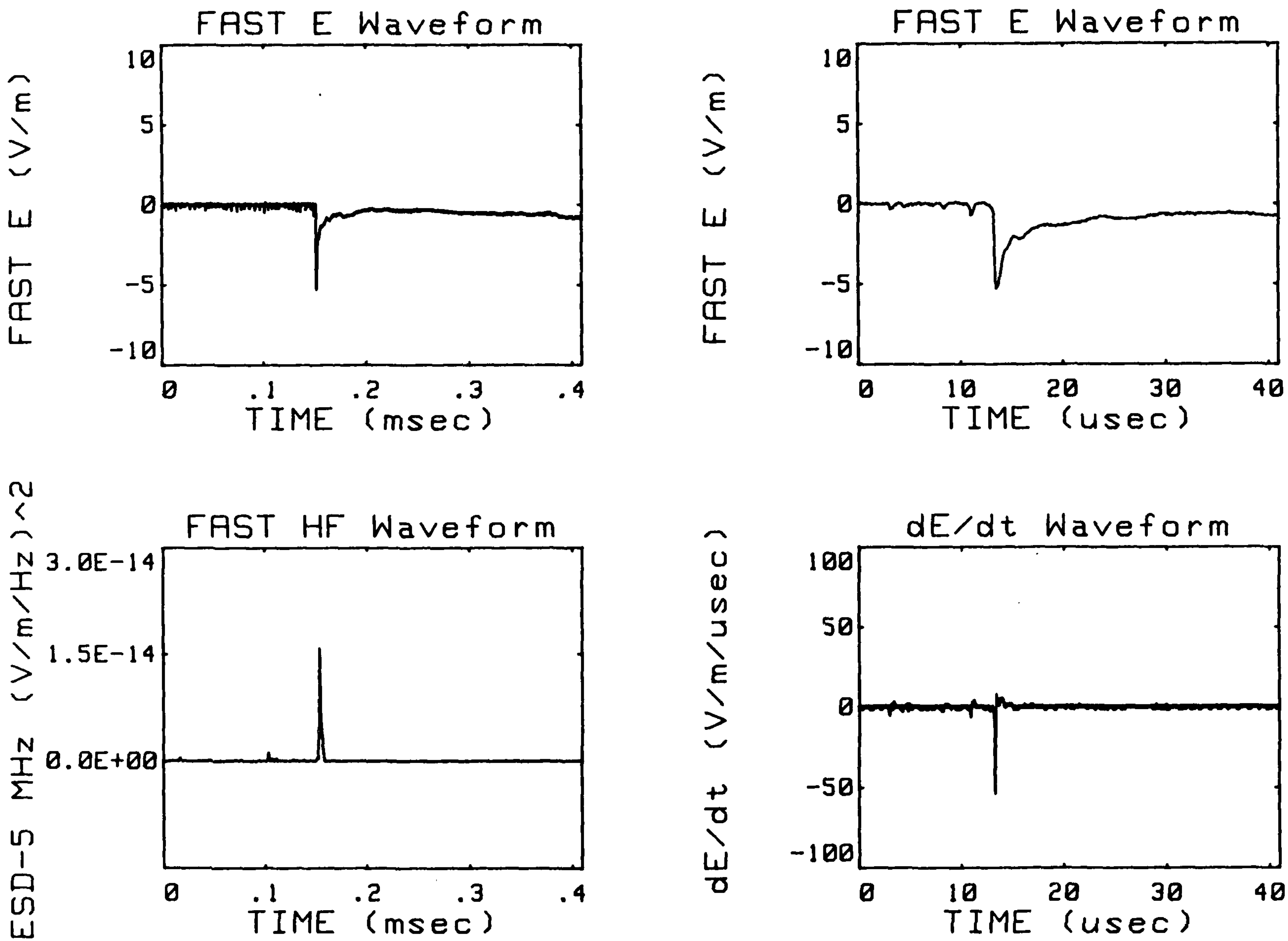


18:08:18.917 14 Aug 1985 (24.5 Km)



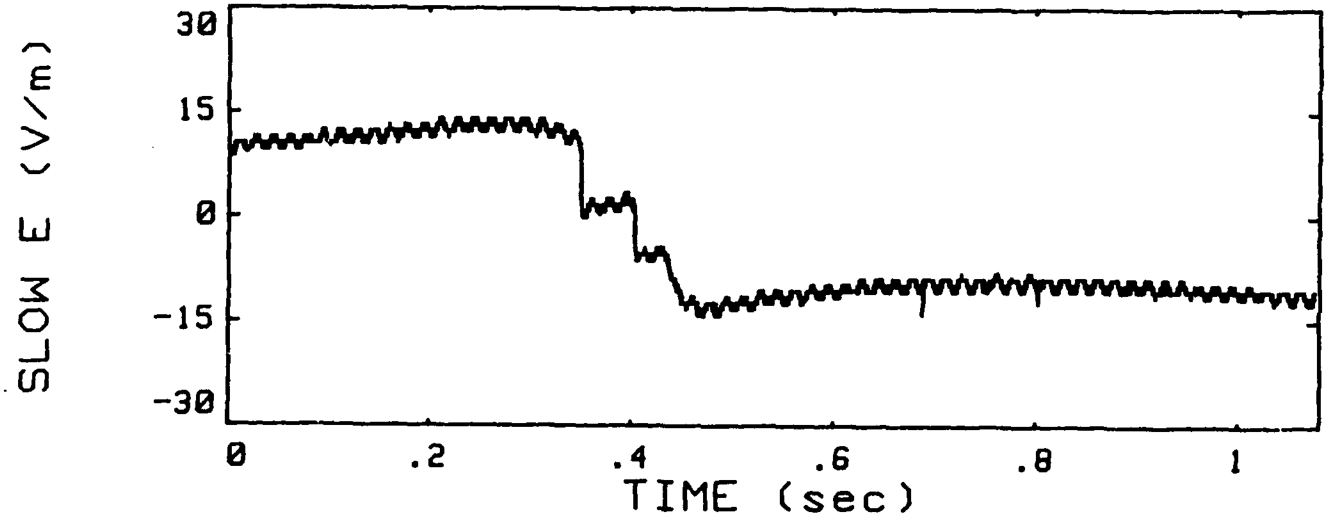


226180835.269 1985 DS Subs RS (28.6 Km)

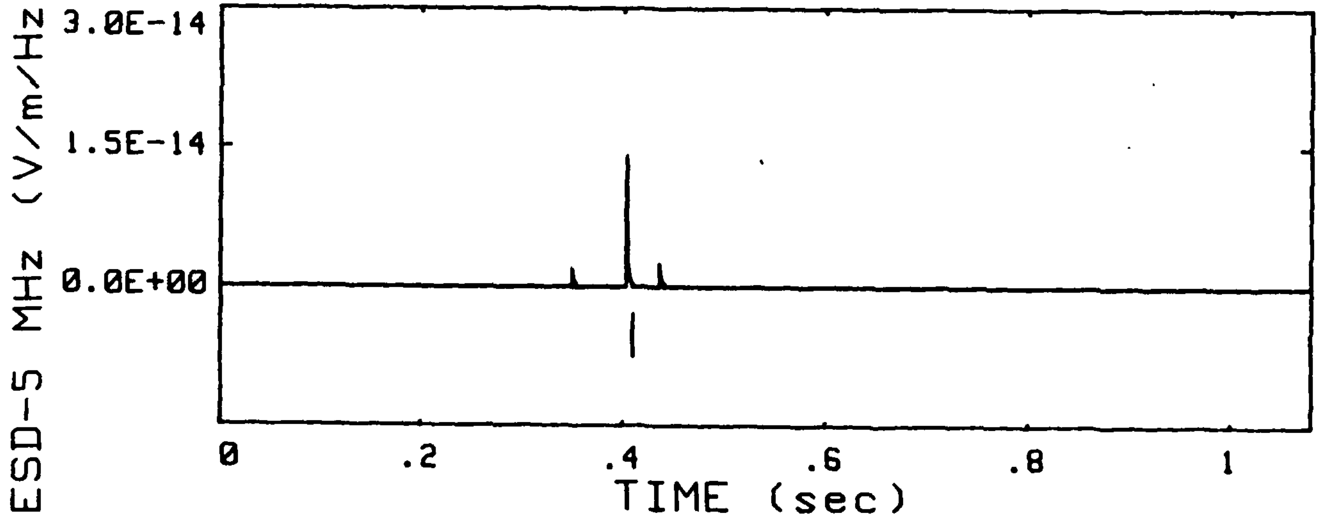


18:08:34.872 14 Aug 1985 (28.6 Km)

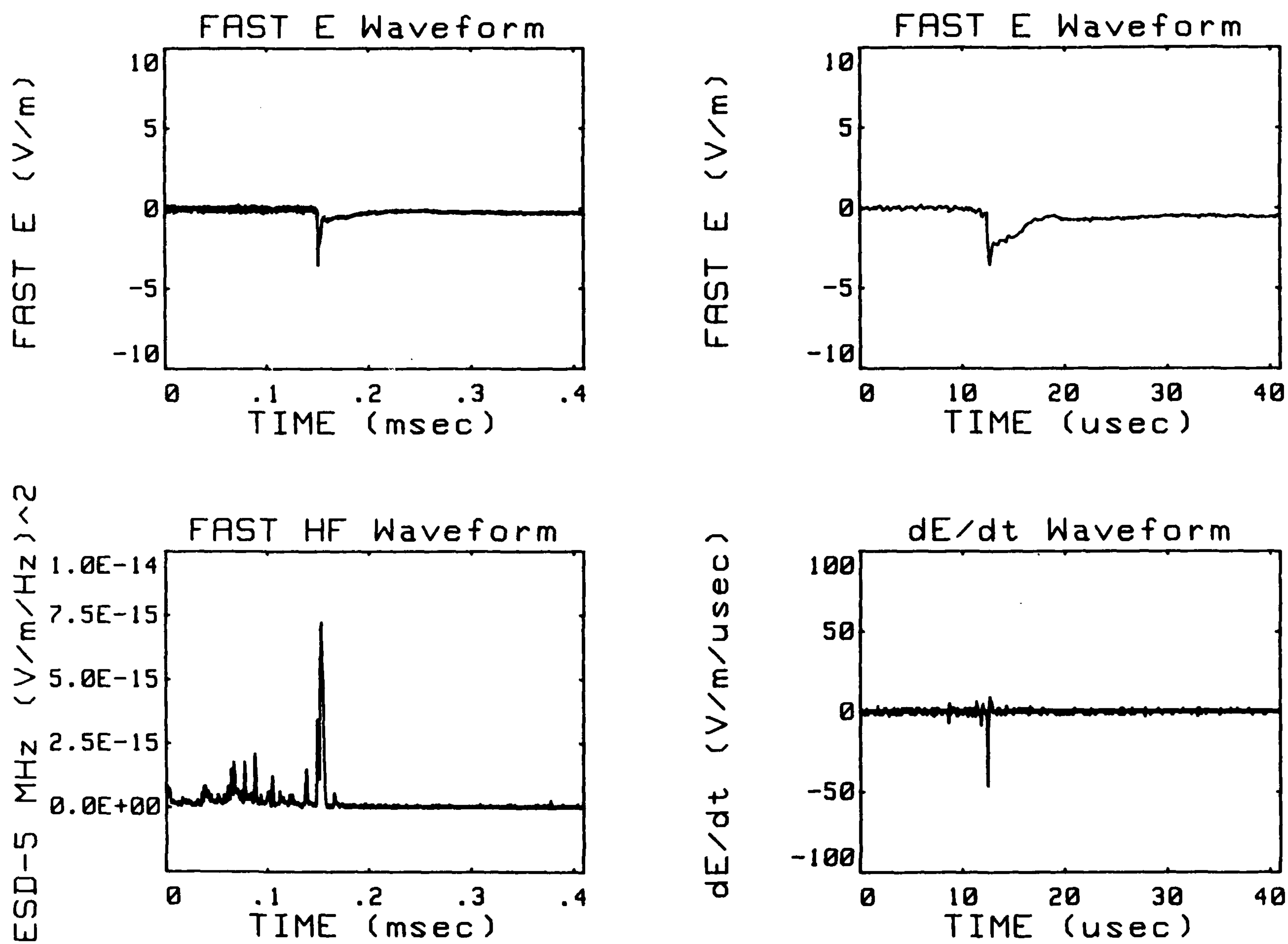
SLOW E Waveform



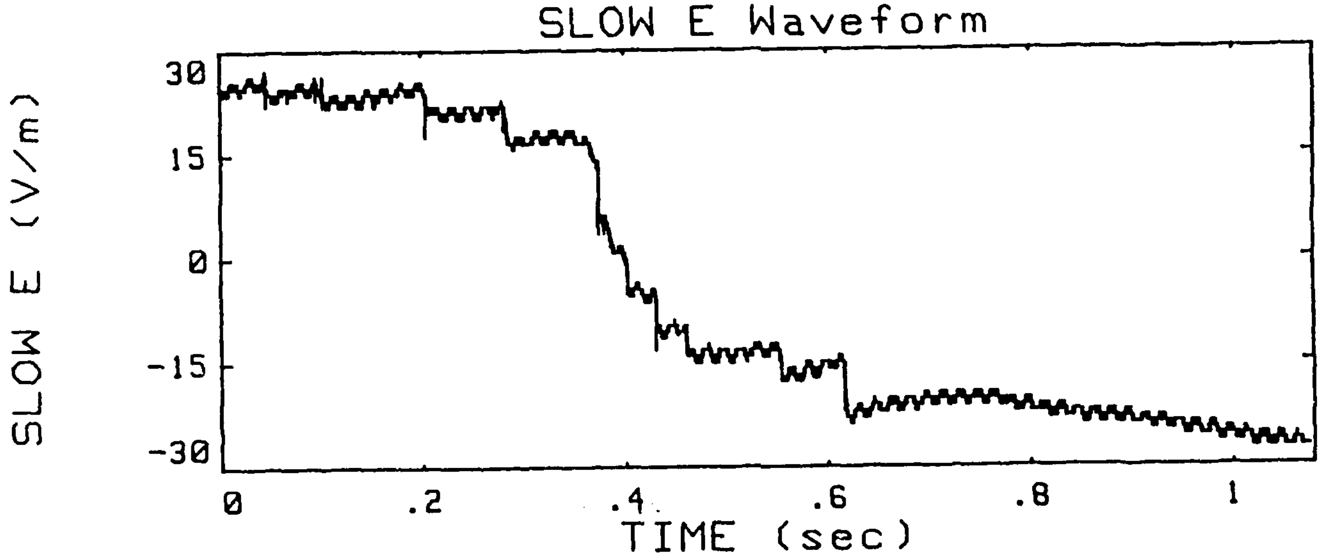
SLOW HF Waveform

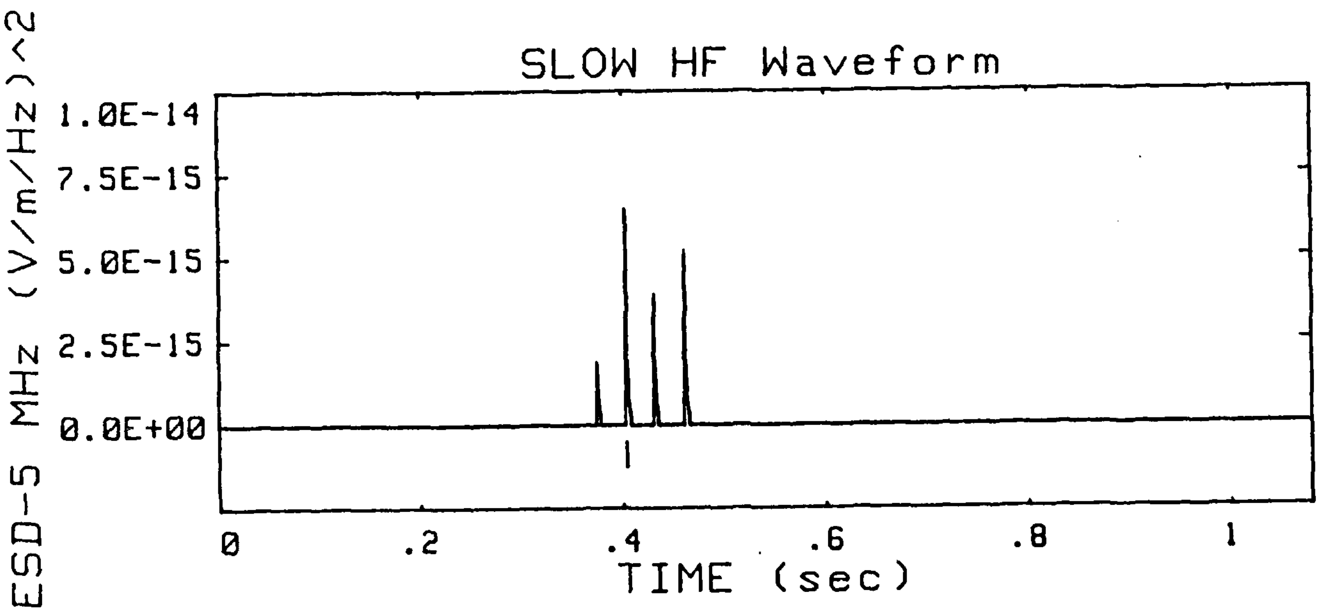


226181100.292 1985 DS Subs RS (32.7 Km)

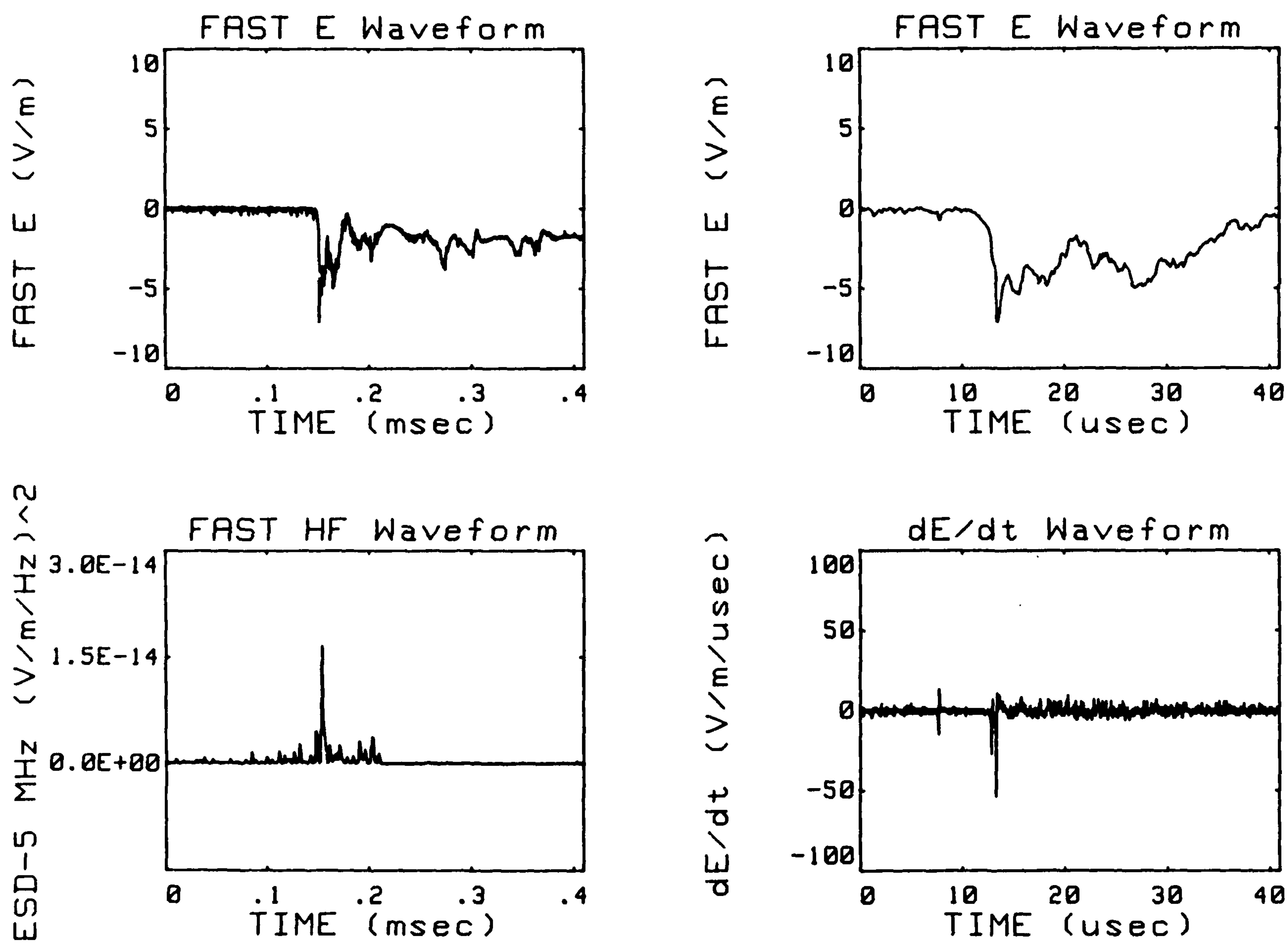


18:10:59.901 14 Aug 1985 (32.7 Km)

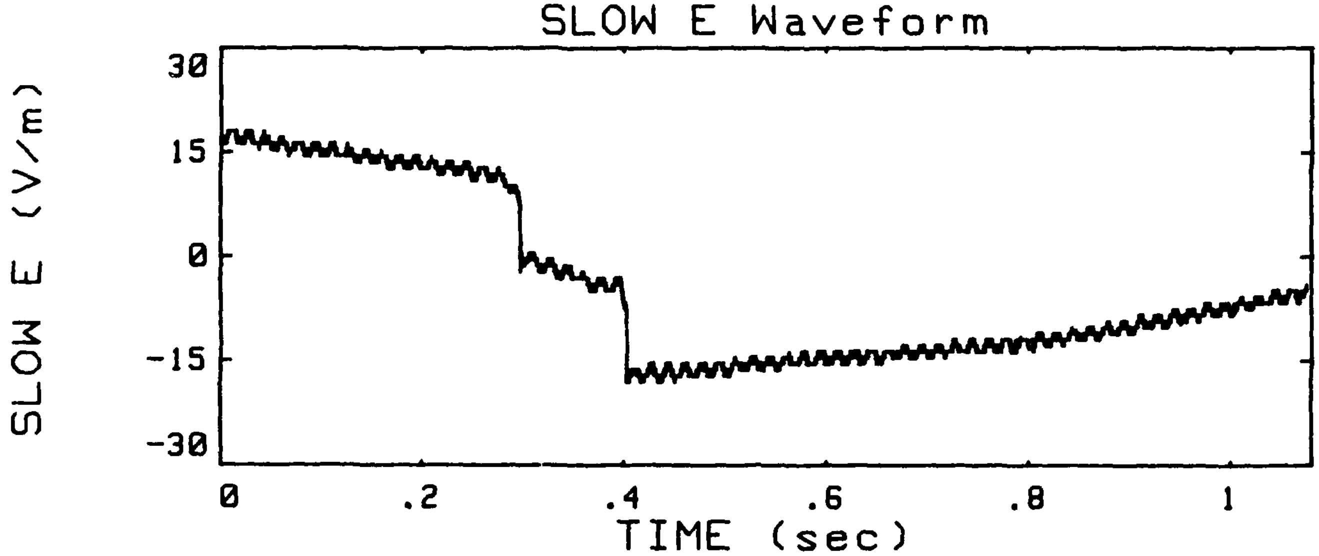


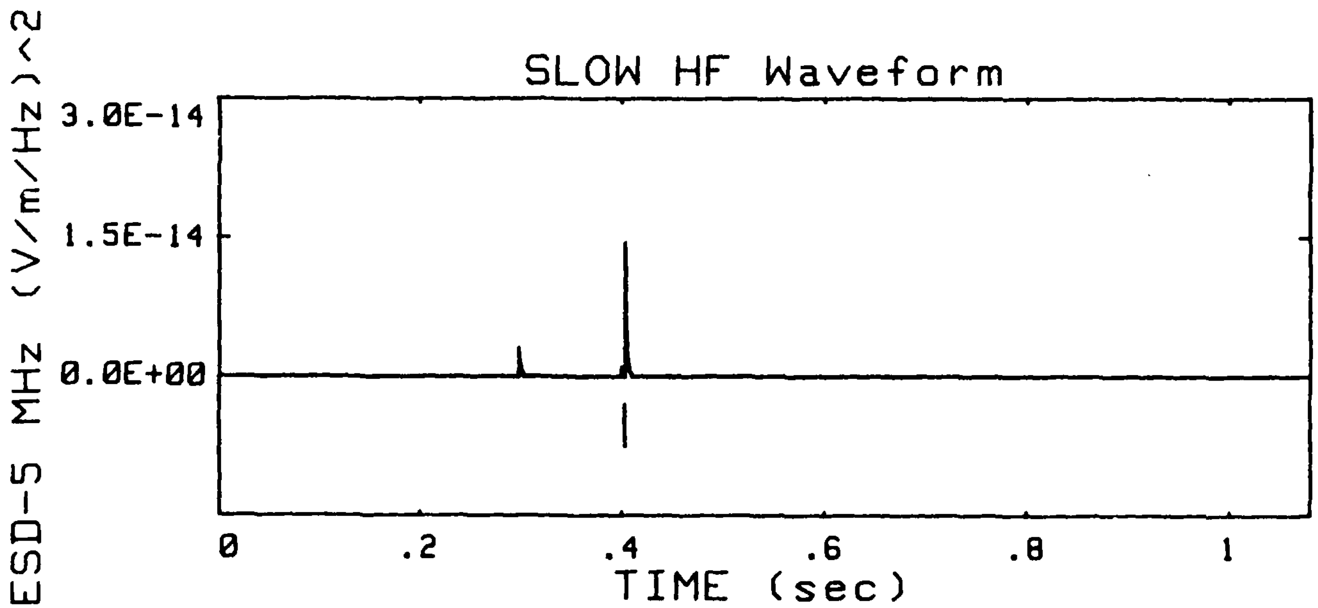


226181116.212 1985 1st RS (30.5 Km)

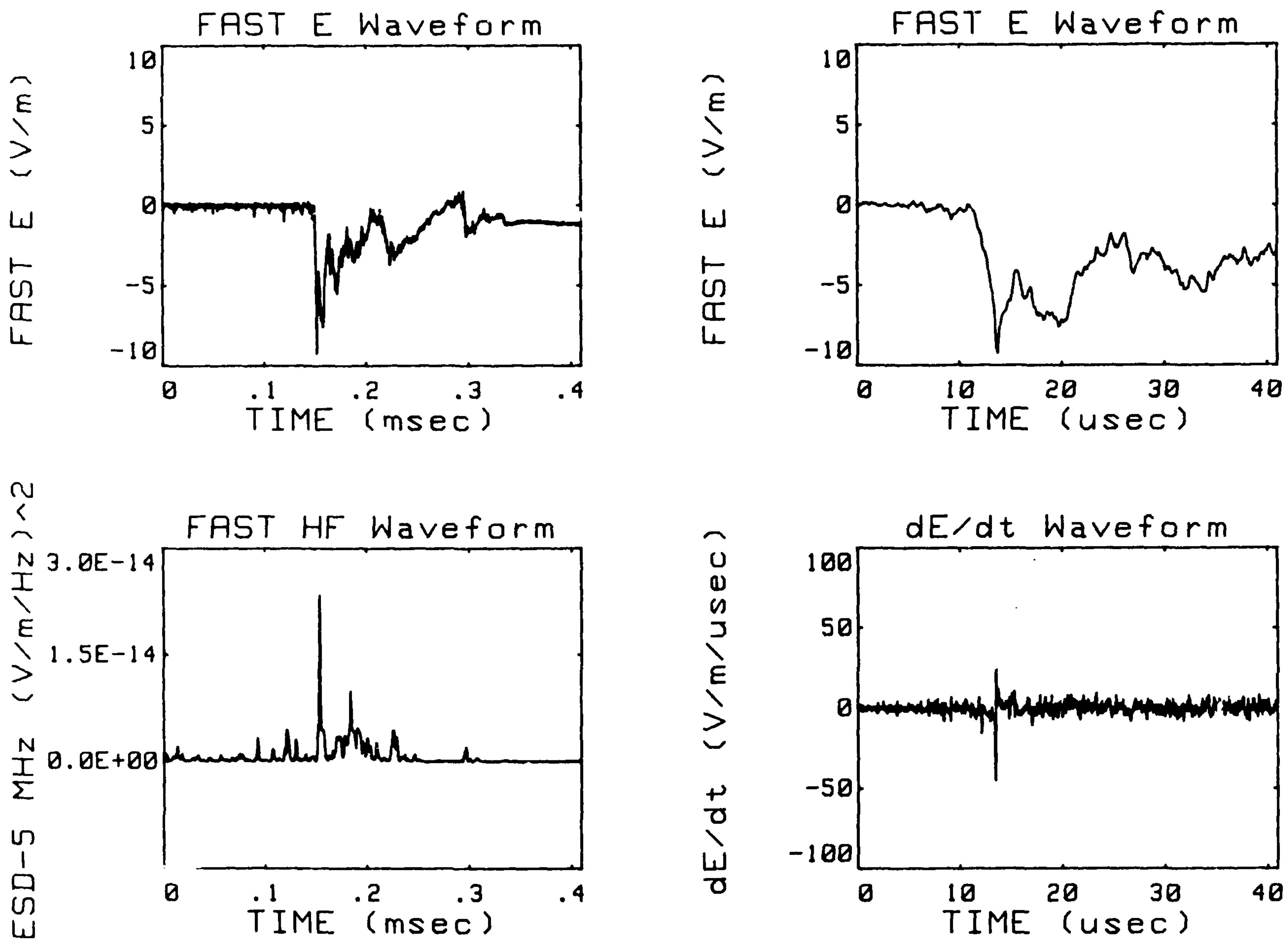


18:11:15.822   14 Aug 1985   (30.5 Km)

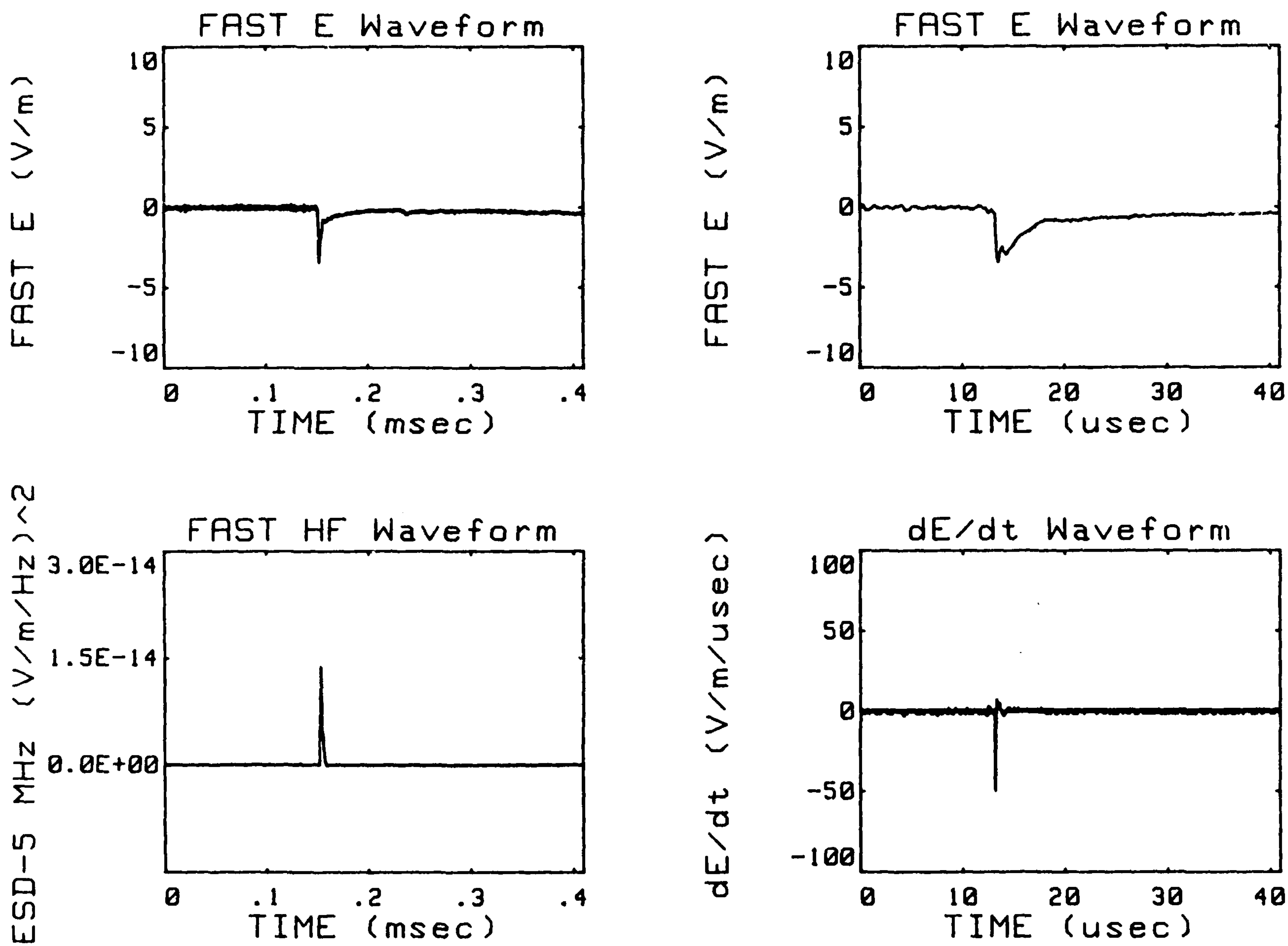




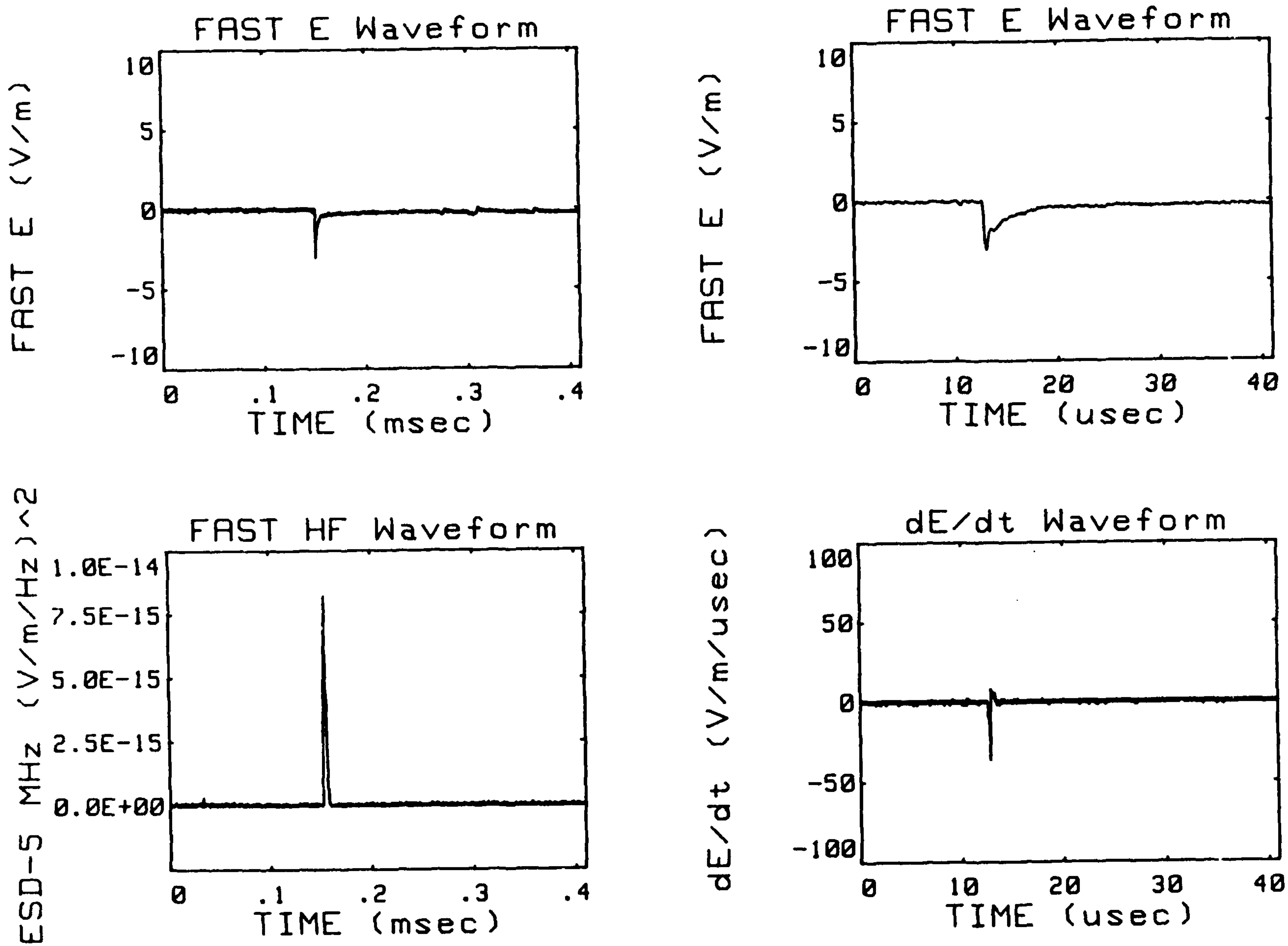
226181138.558 1985 1st RS (29.8 Km)



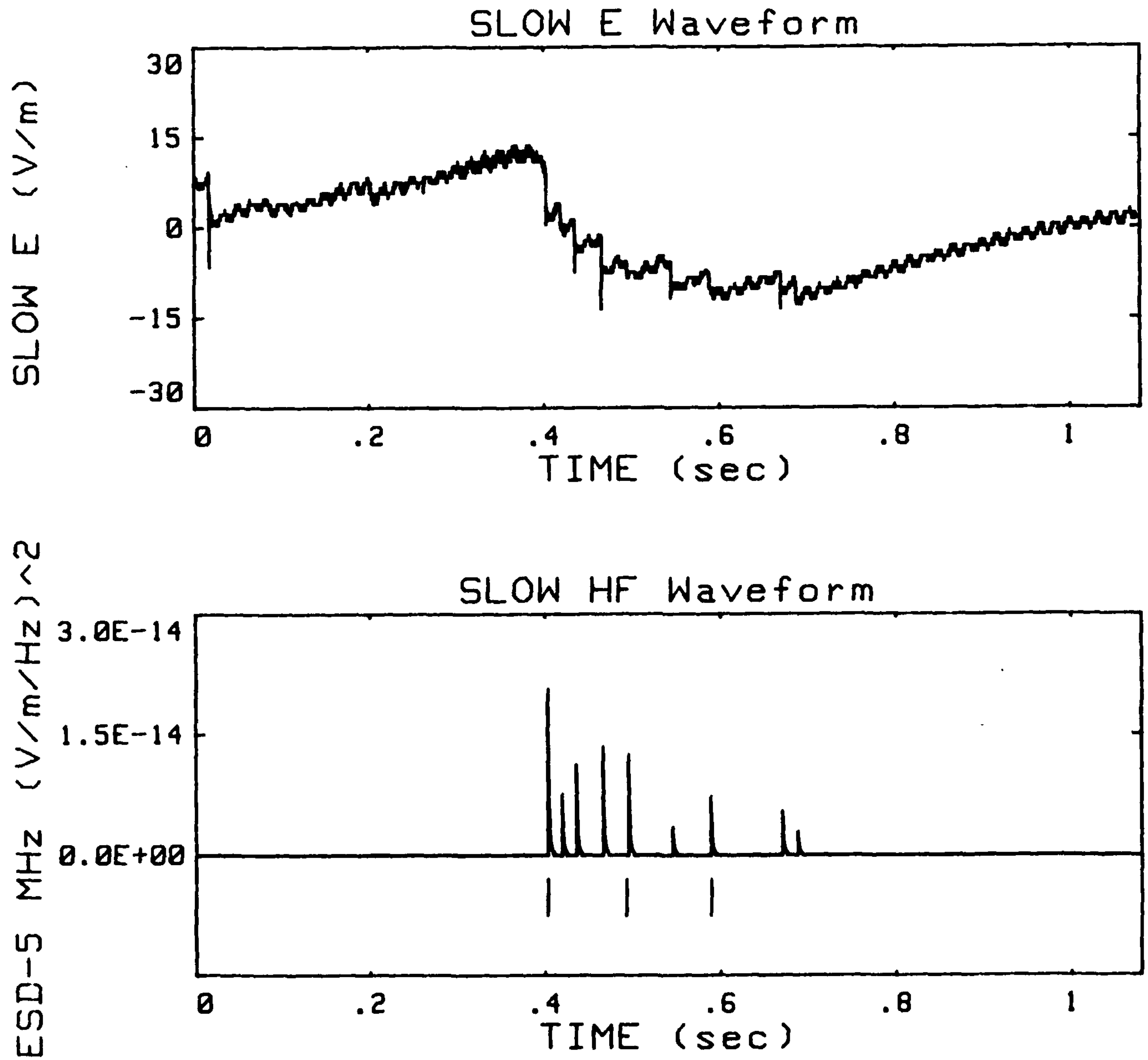
226181138.648   1985   Norm Subs RS   (29.8 Km)



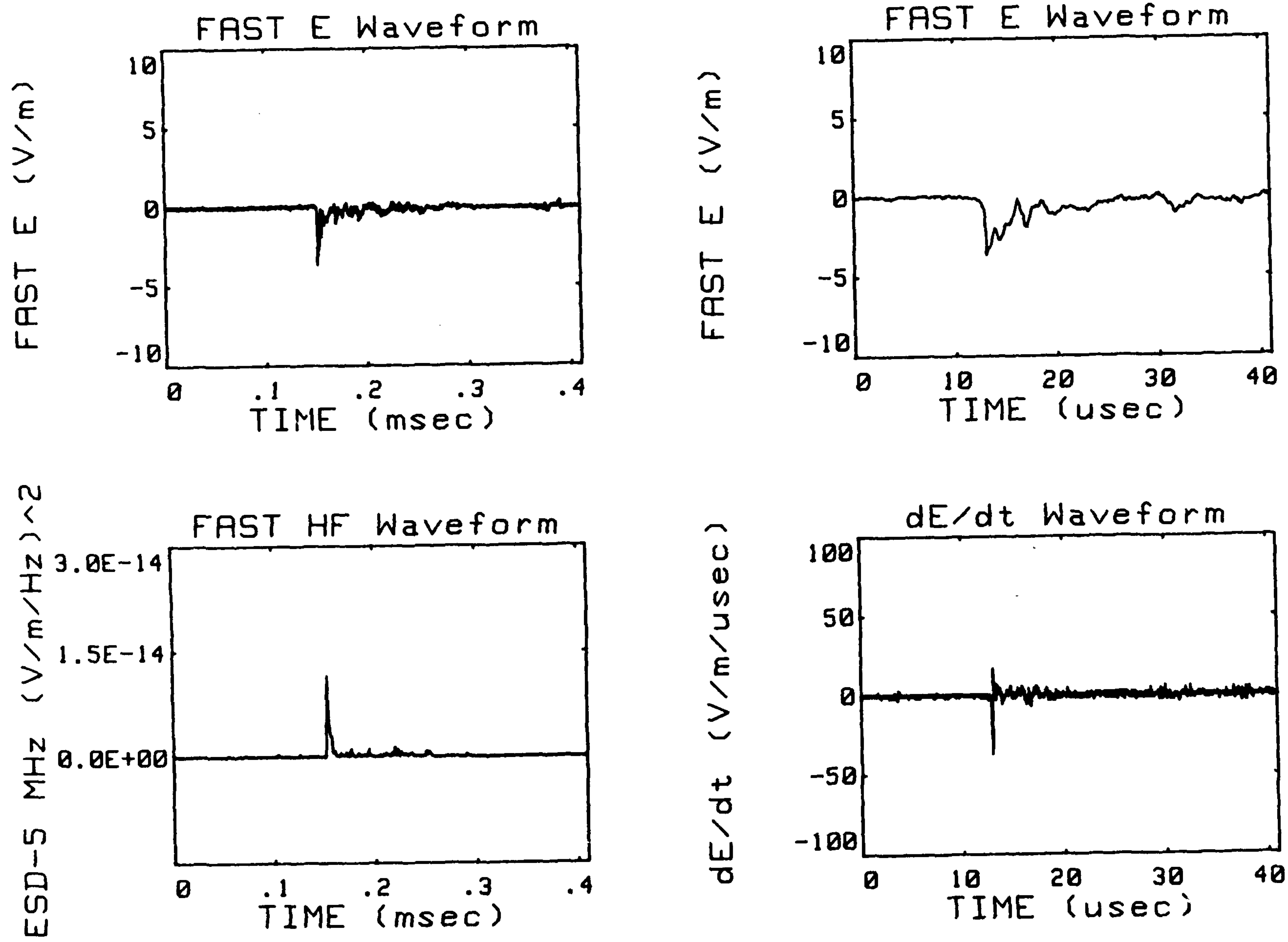
226181138.745 1985 DS Subs RS (29.8 Km)



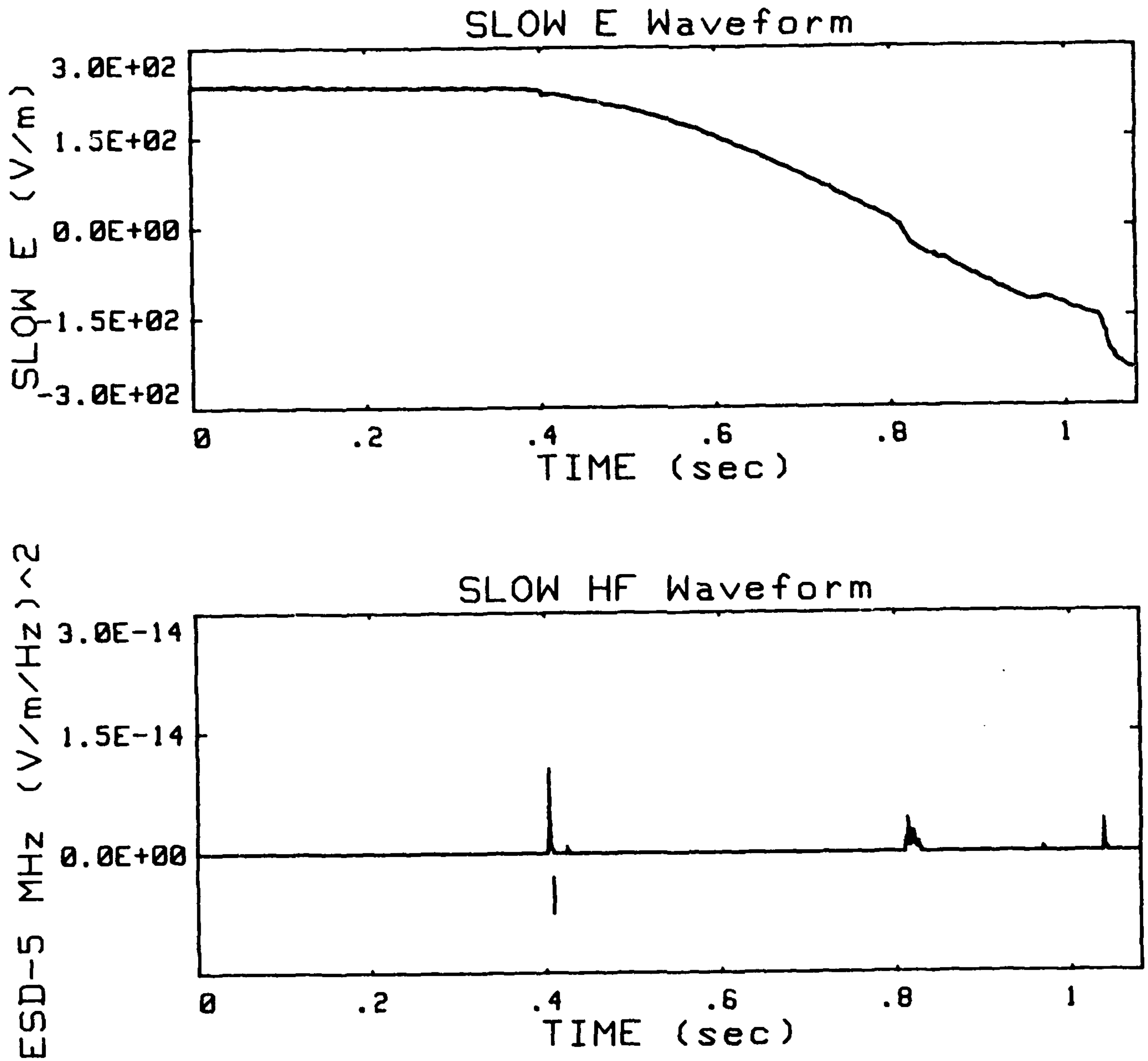
18:11:38.168 14 Aug 1985 (29.8 Km)



226181216.300 1985 1st RS (30.4 Km)



18:12:15.904 14 Aug 1985 (30.4 Km)



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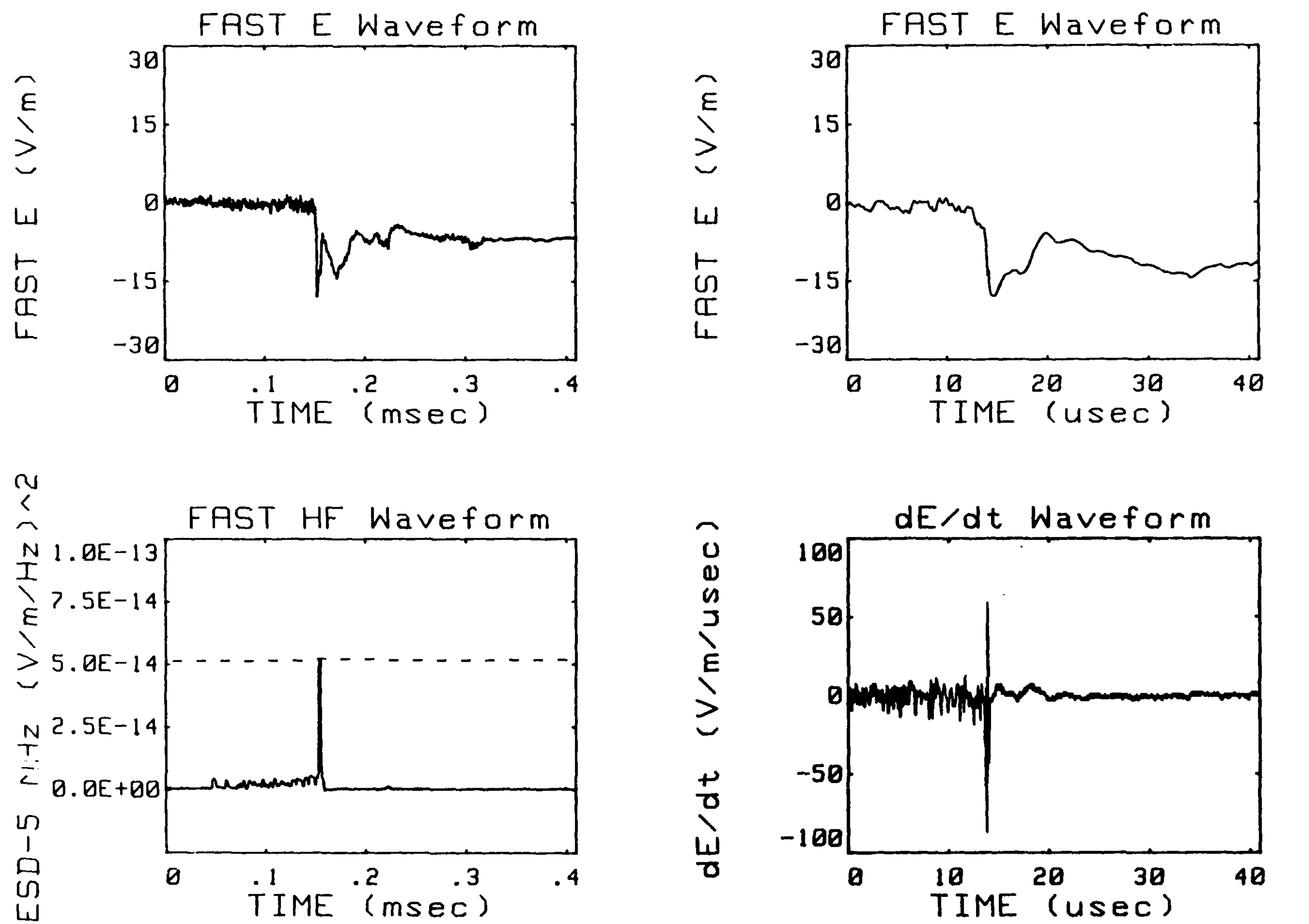
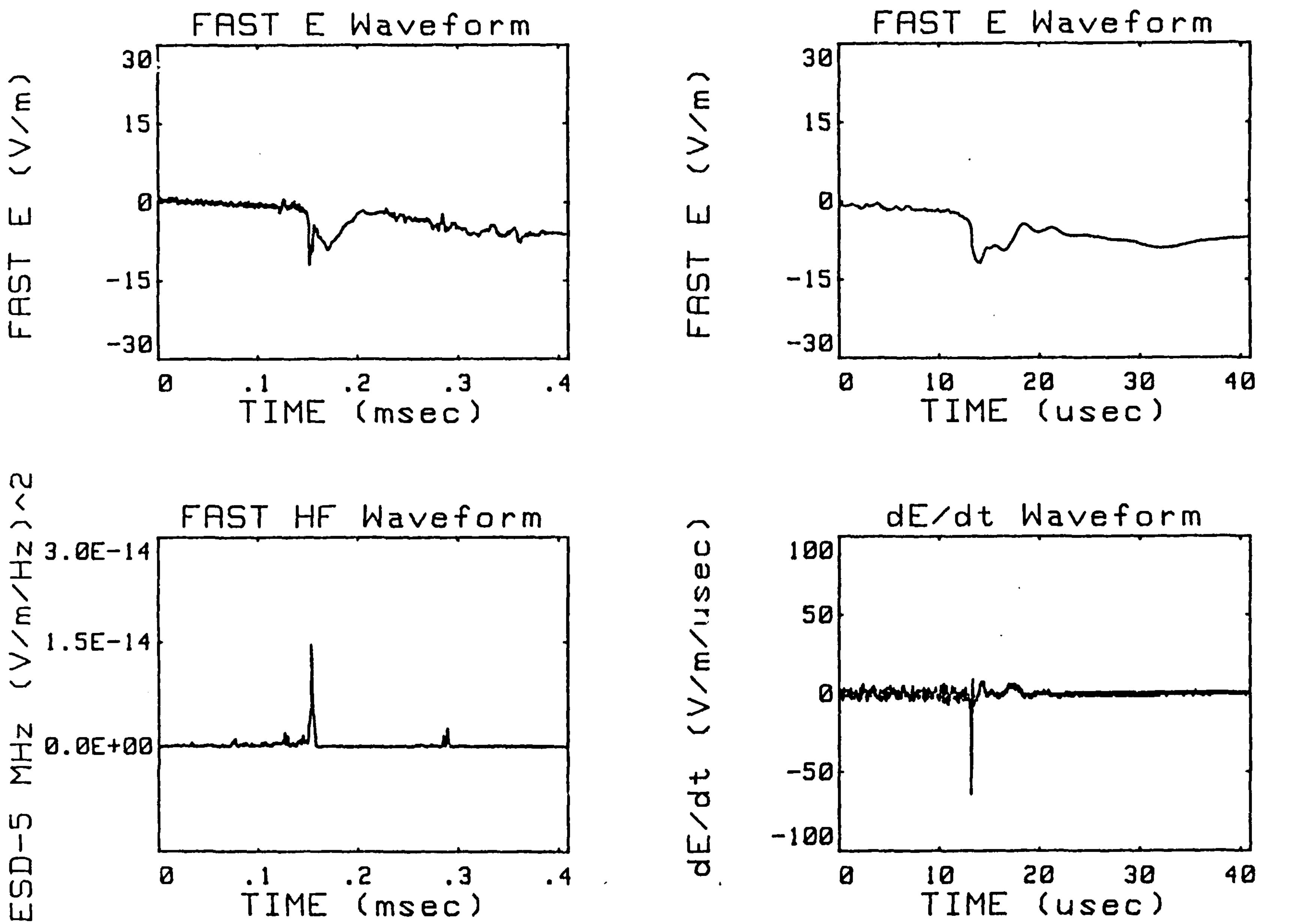
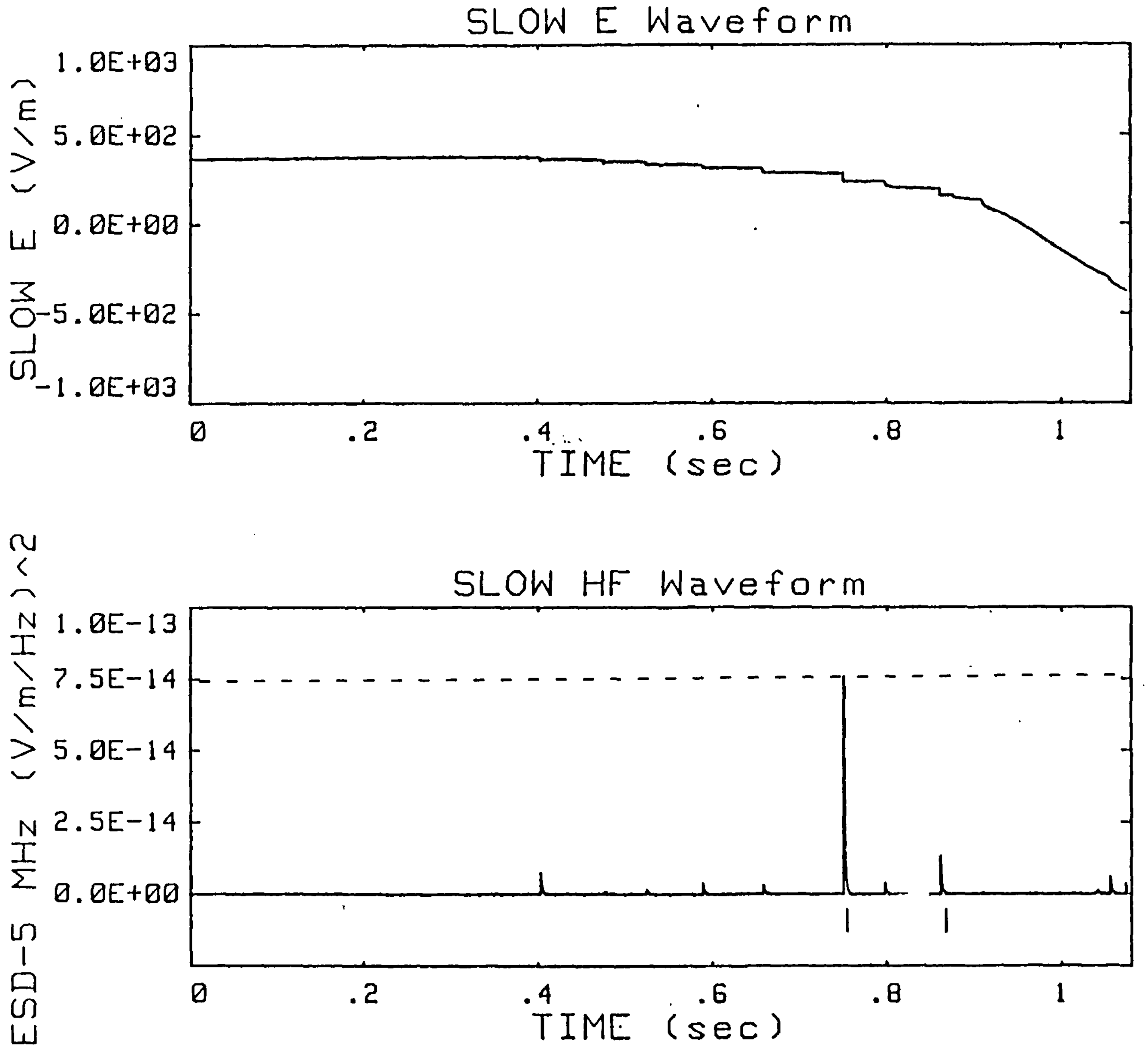
226181306.467 1985 Chaotic Subs RS (31.3 Km)



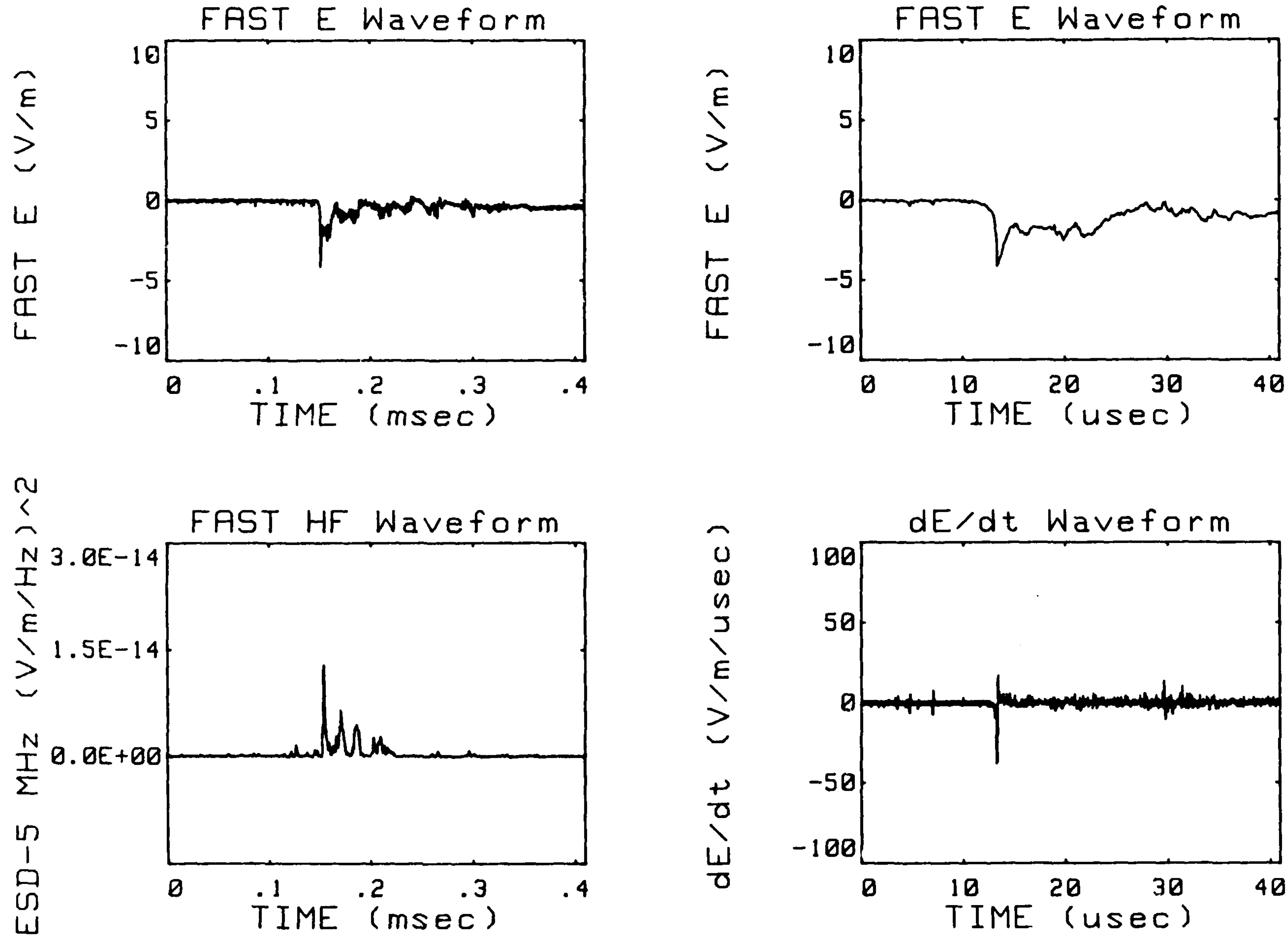
226181306.581 1985 Chaotic Subs RS (31.3 Km)



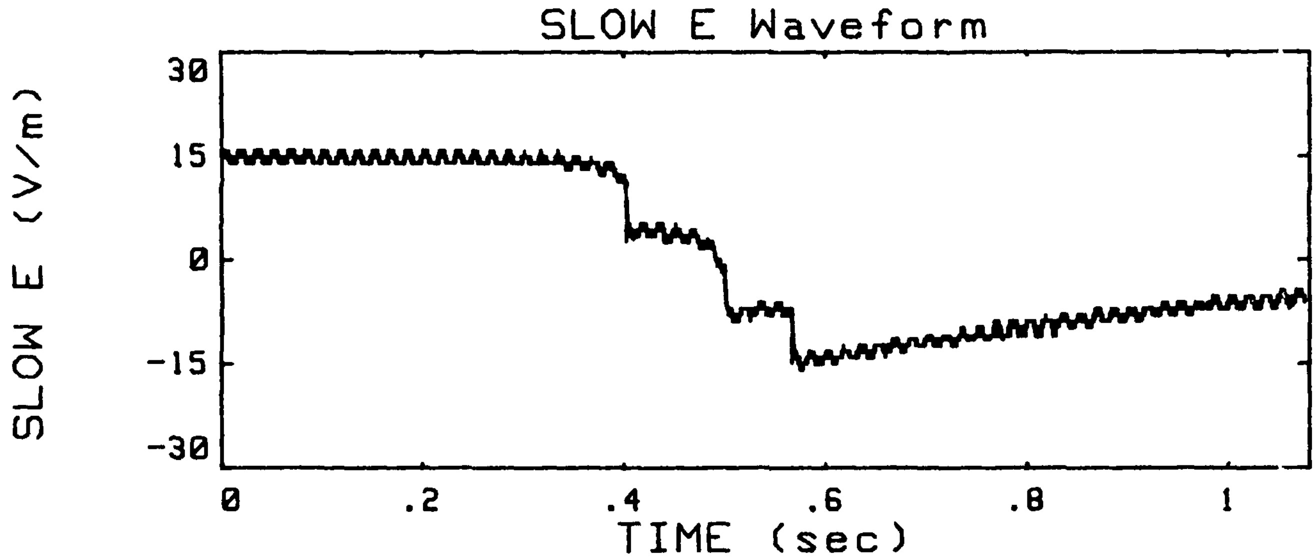
18:13:05.728 14 Aug 1985 (31.3 Km)

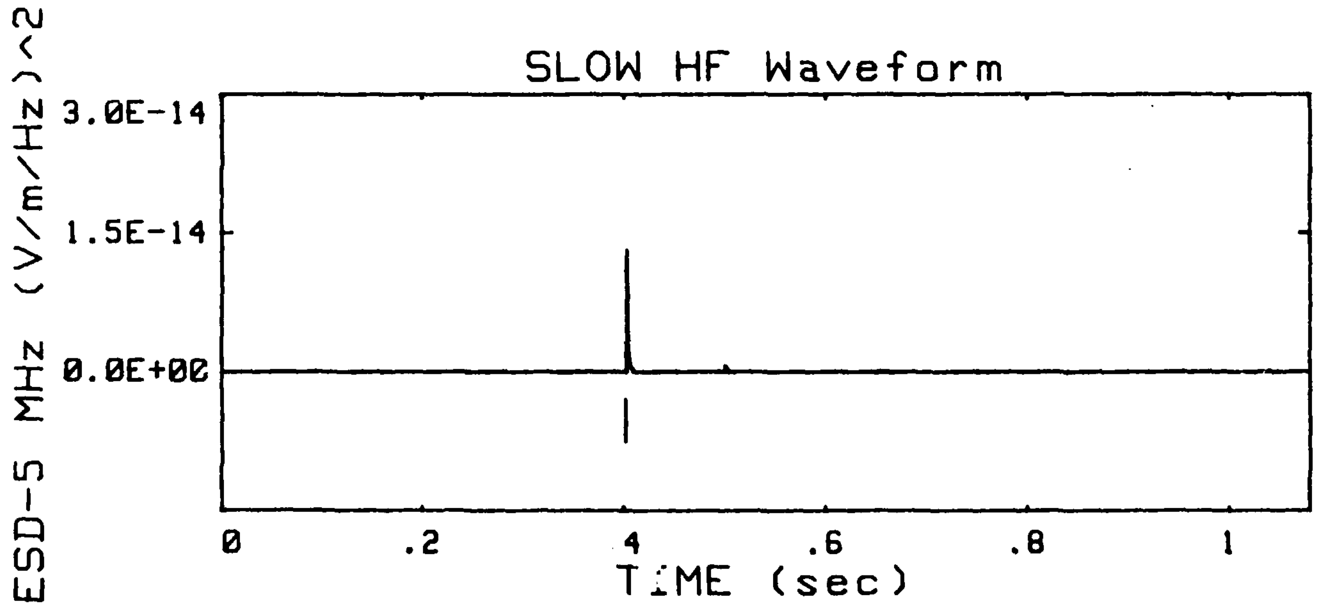


226181323.055 1985 1st RS (27.6 Km)

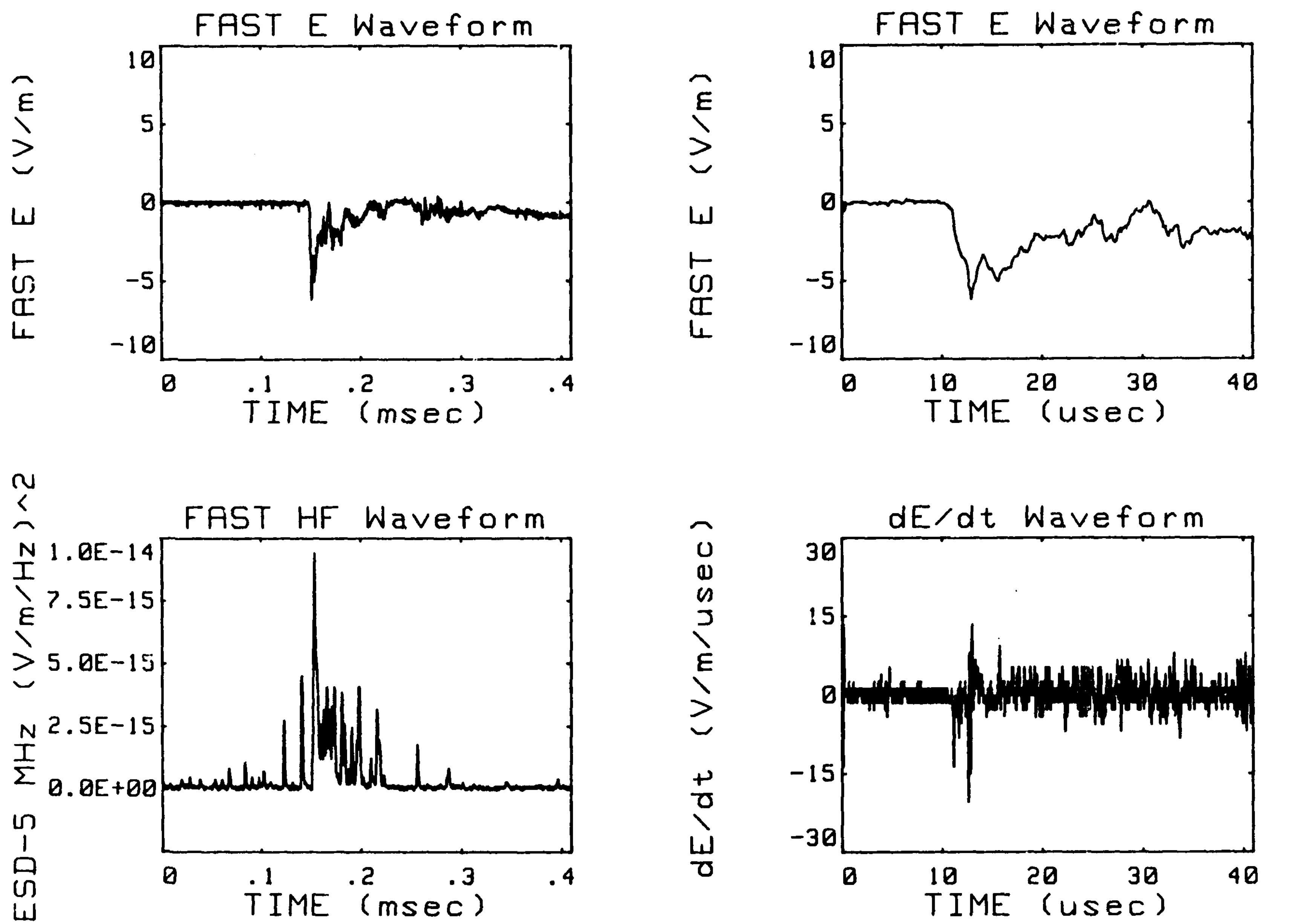


18:13:22.666 14 Aug 1985 (27.6 Km)

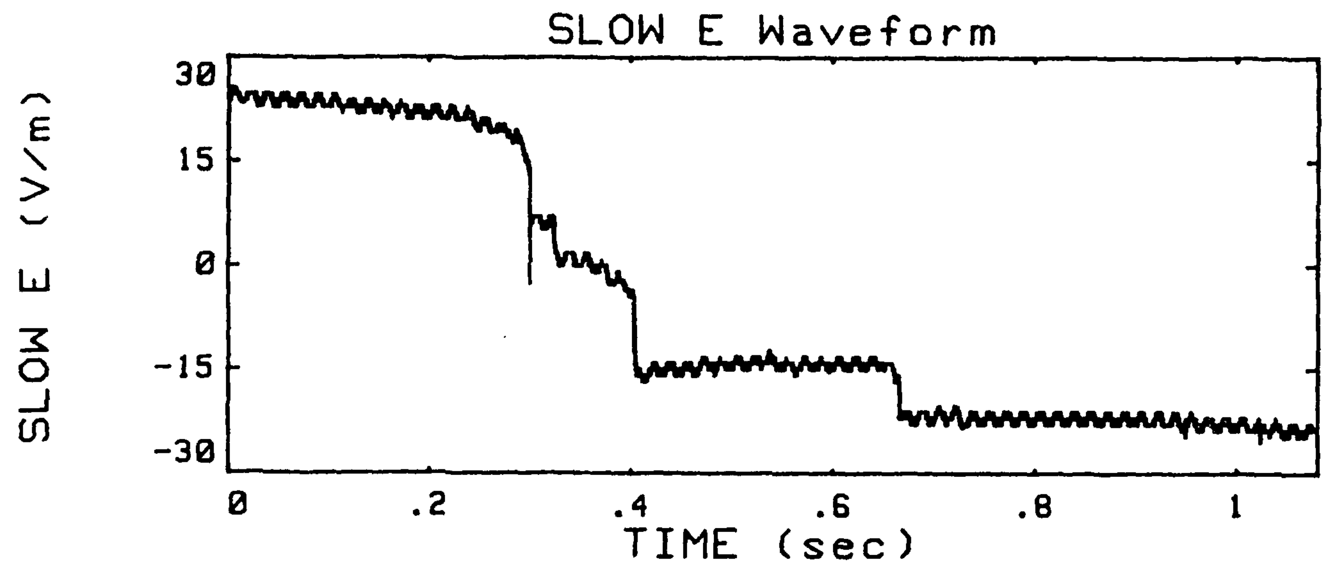


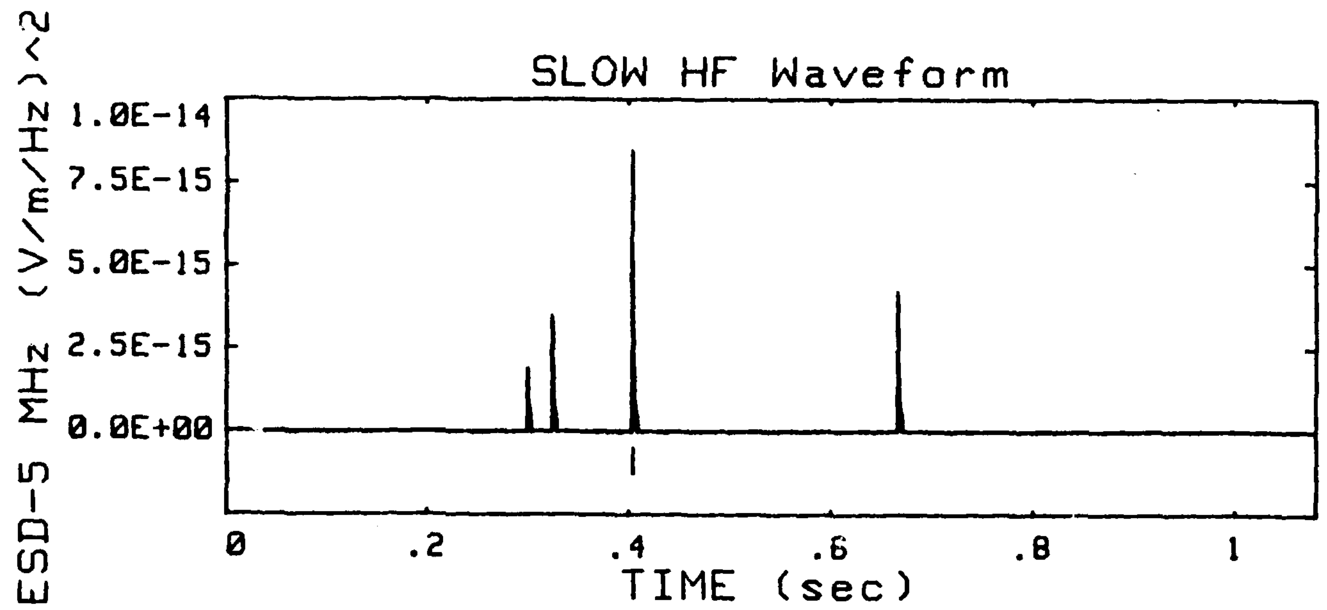


226181348.557 1985 1st RS (32.7 Km)

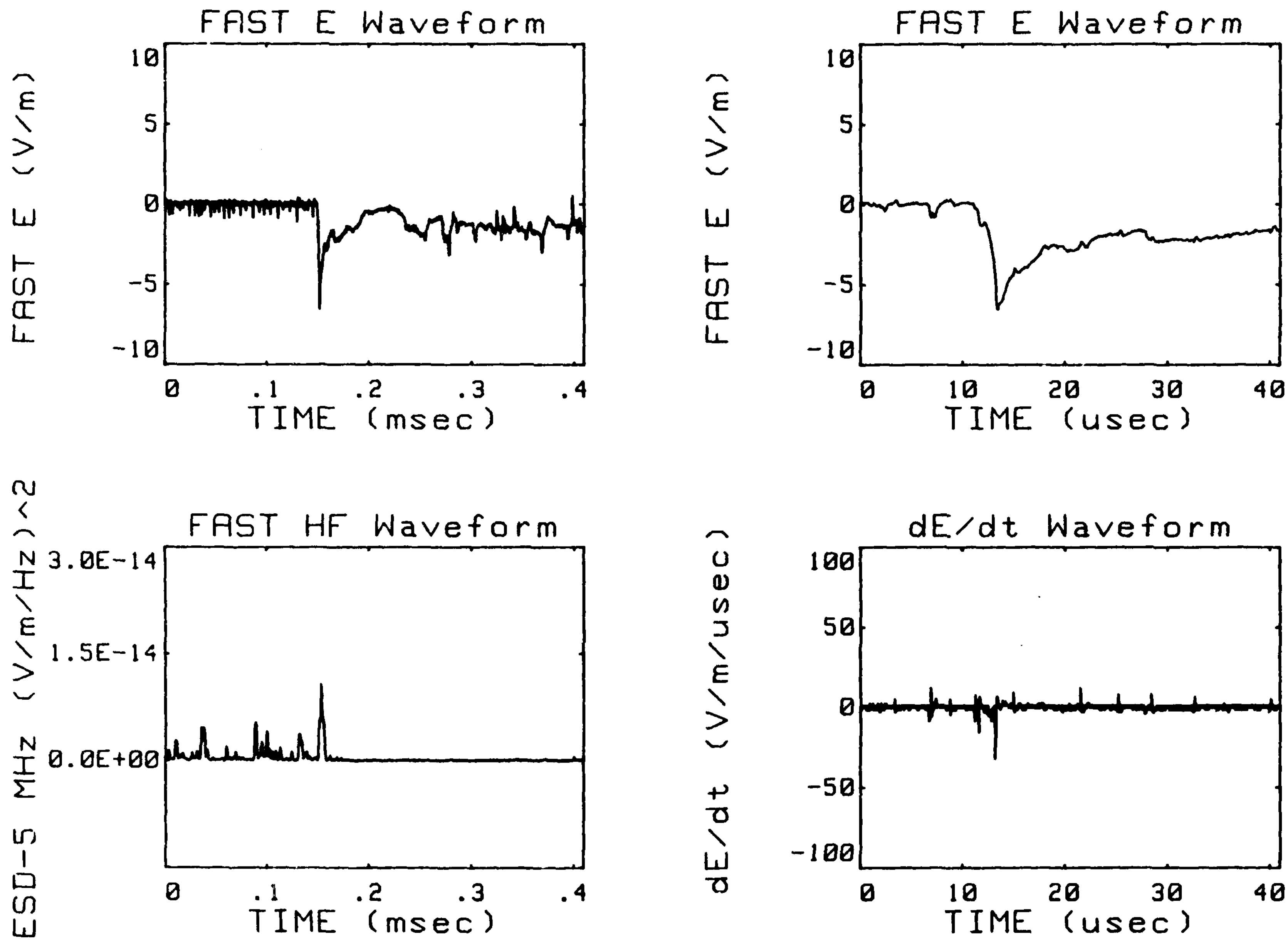


18:13:48.166 14 Aug 1985 (32.7 Km)

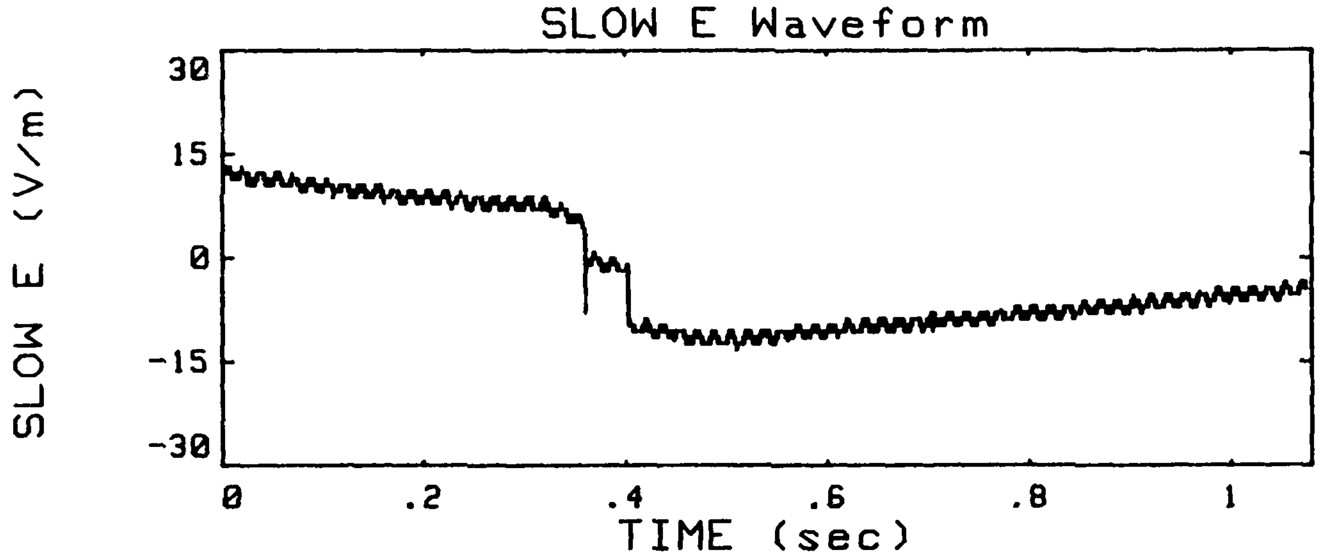


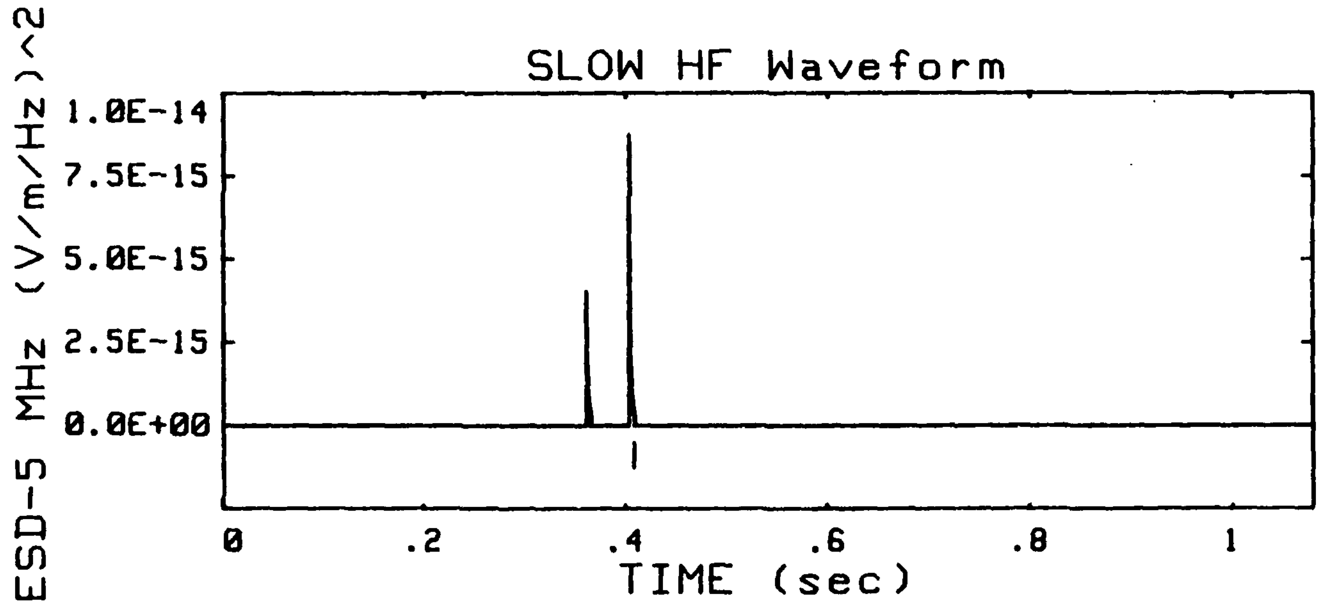


226181435.484 1985 DS Subs RS (33.3 Km)

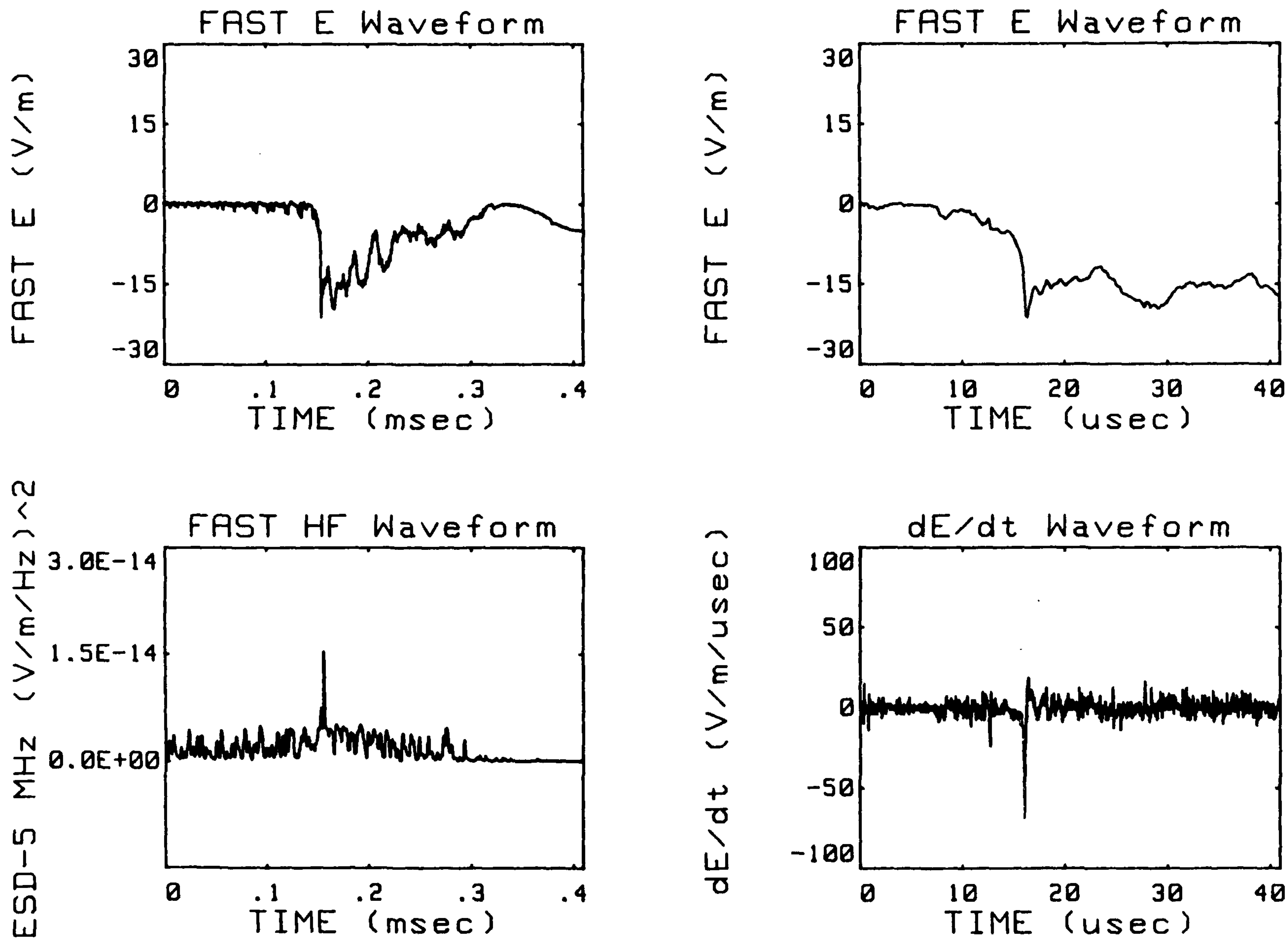


18:14:35.089 14 Aug 1985 (33.3 Km)

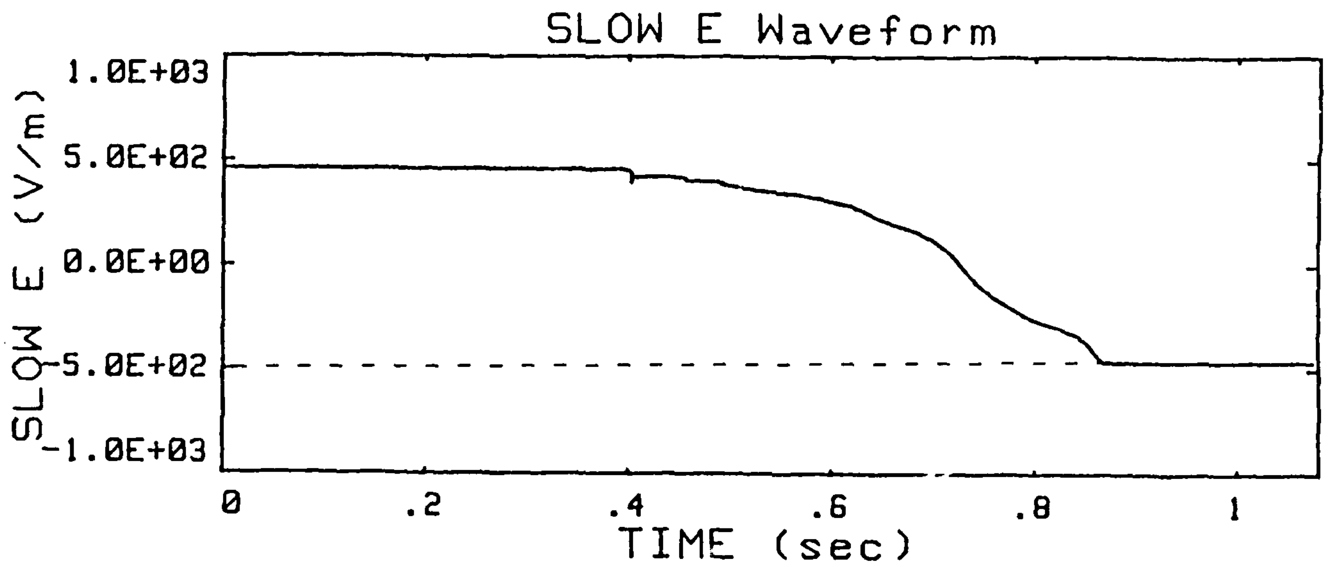


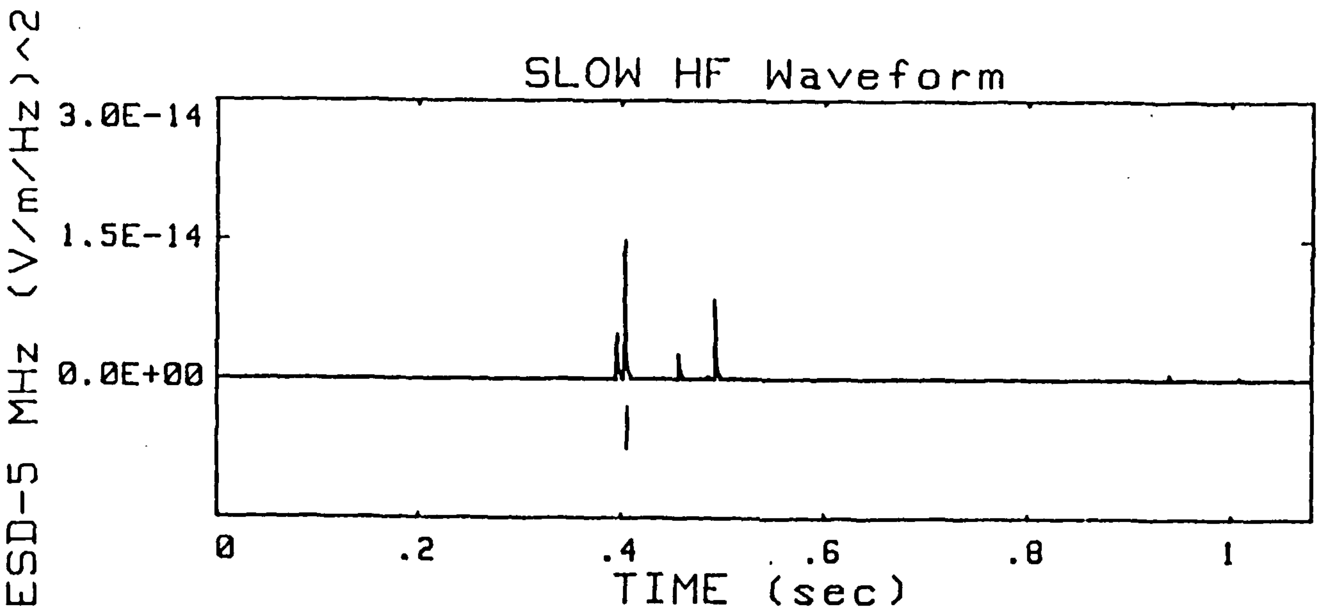


226181807.335   1985   1st RS (30.2 Km)

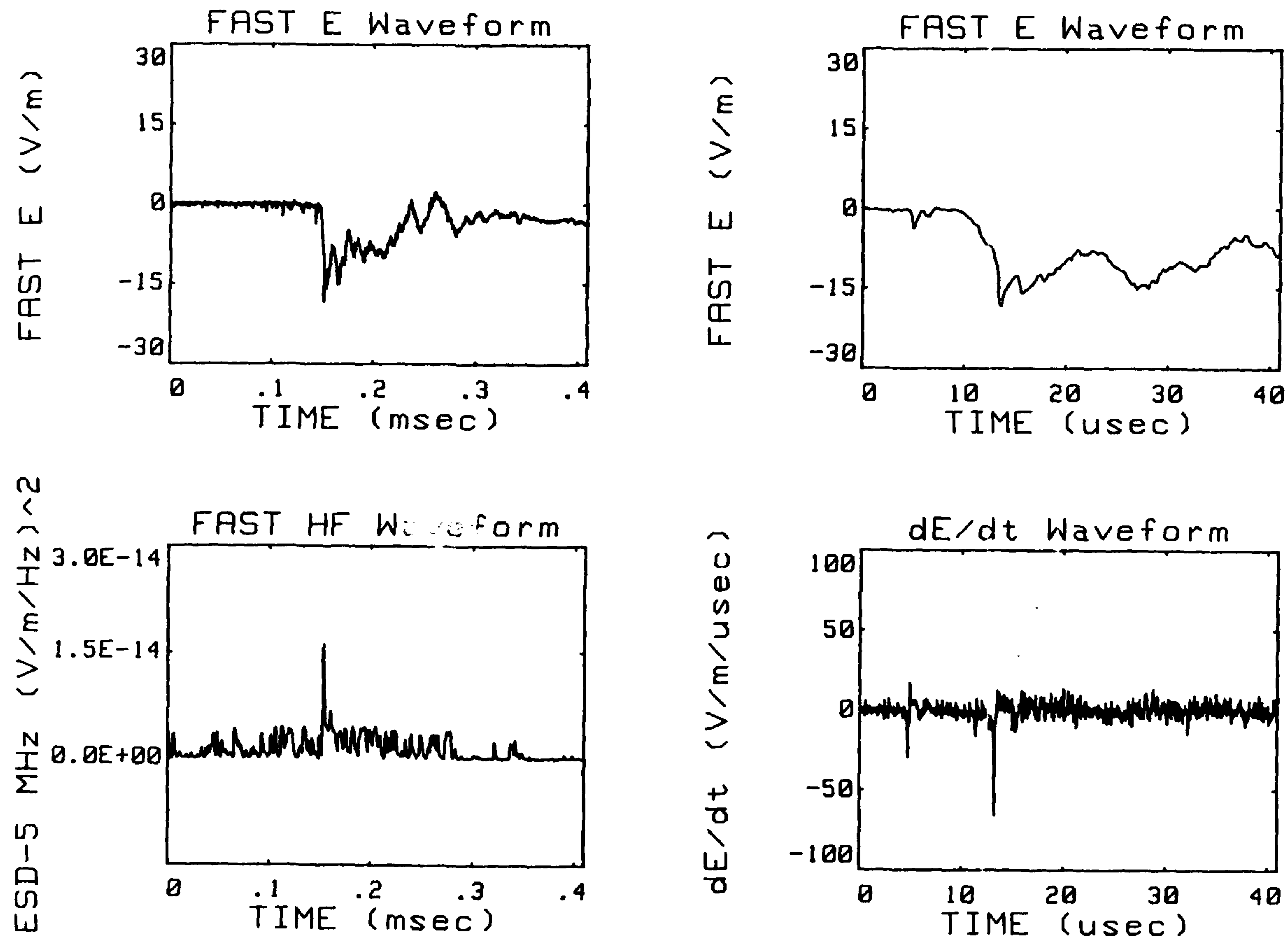


18:18:06.942 14 Aug 1985 (30.2 Km)

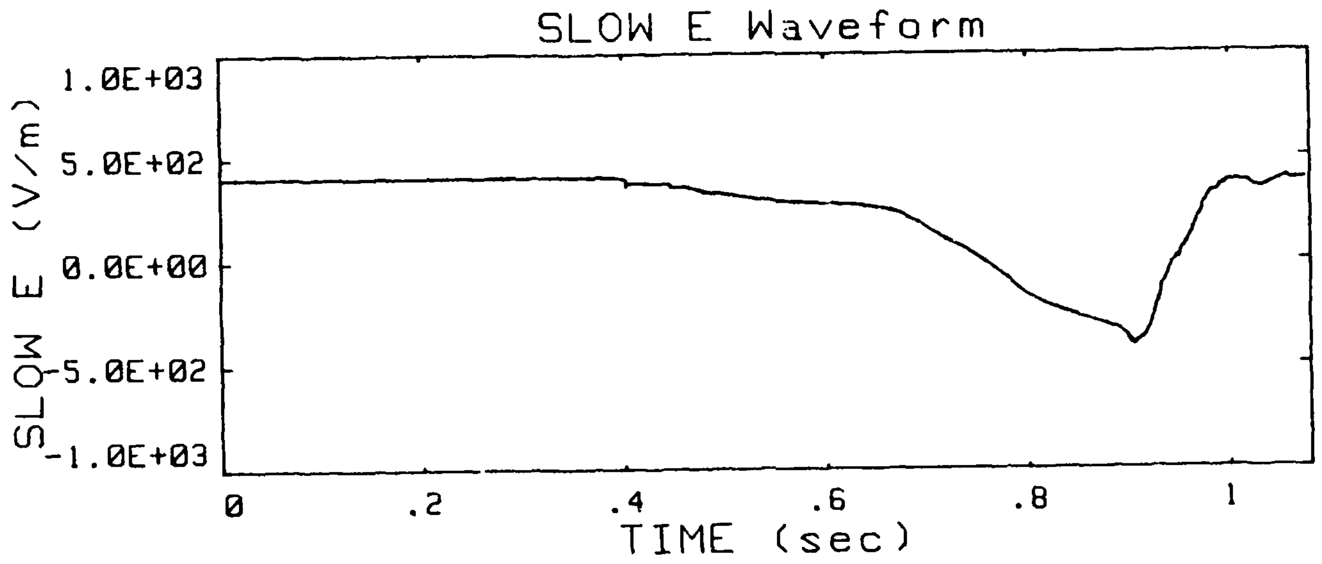


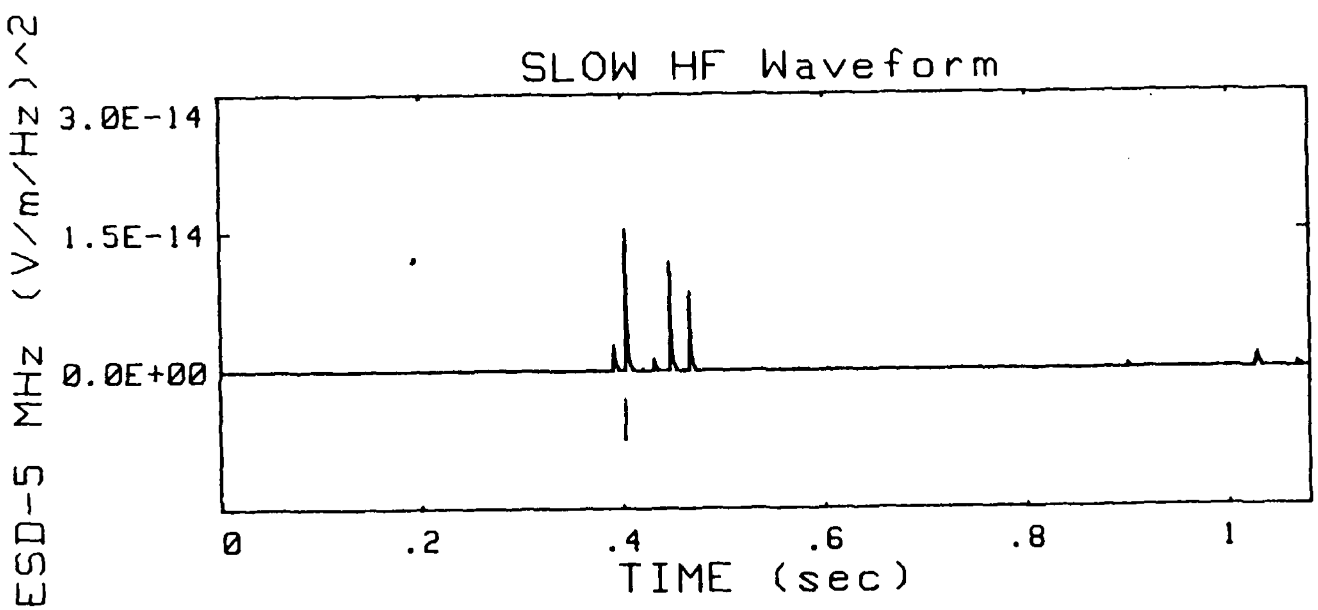


226181913.527 1985 1st RS (29.4 Km)

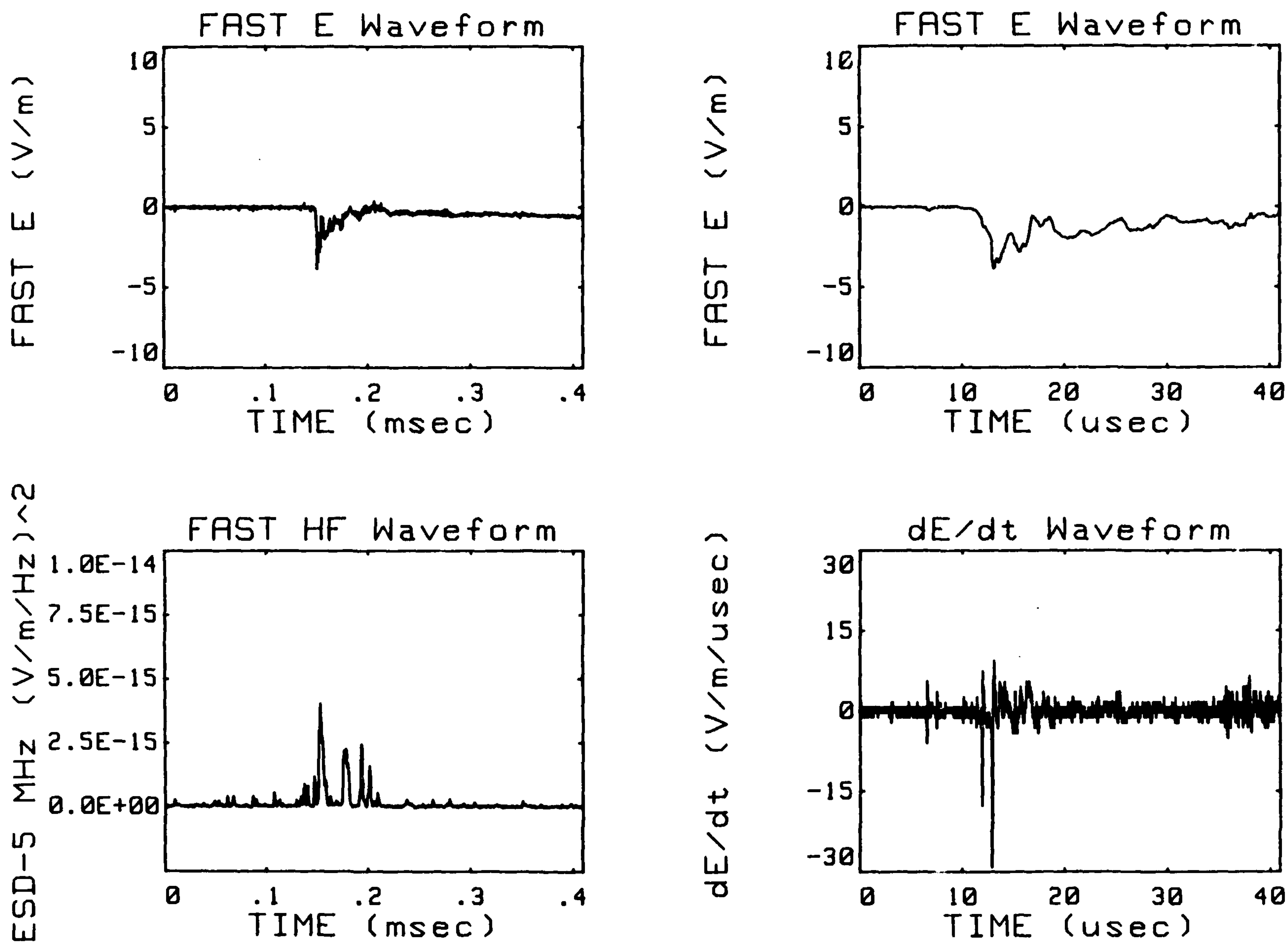


18:19:13.137 14 Aug 1985 (29.4 Km)

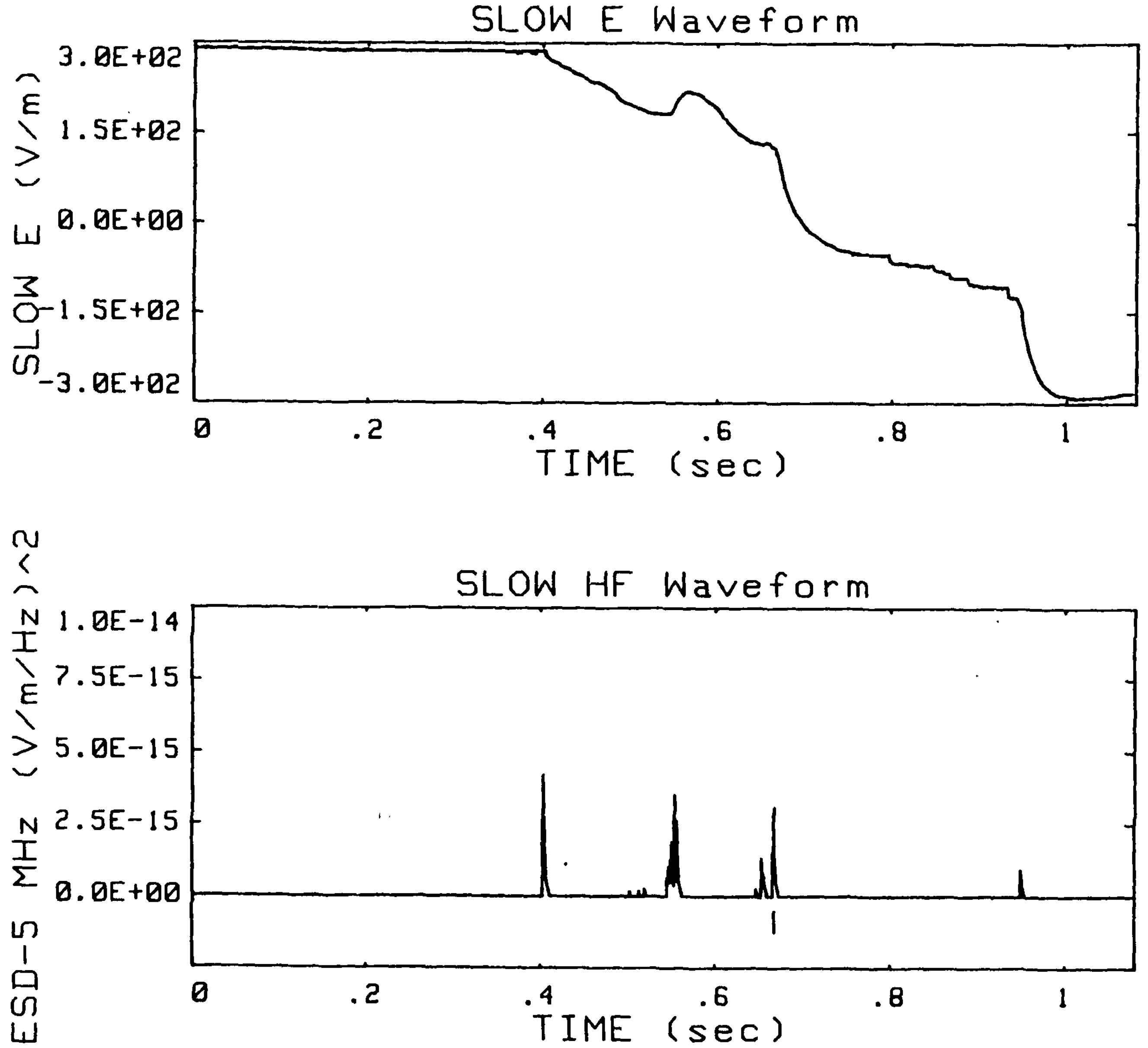




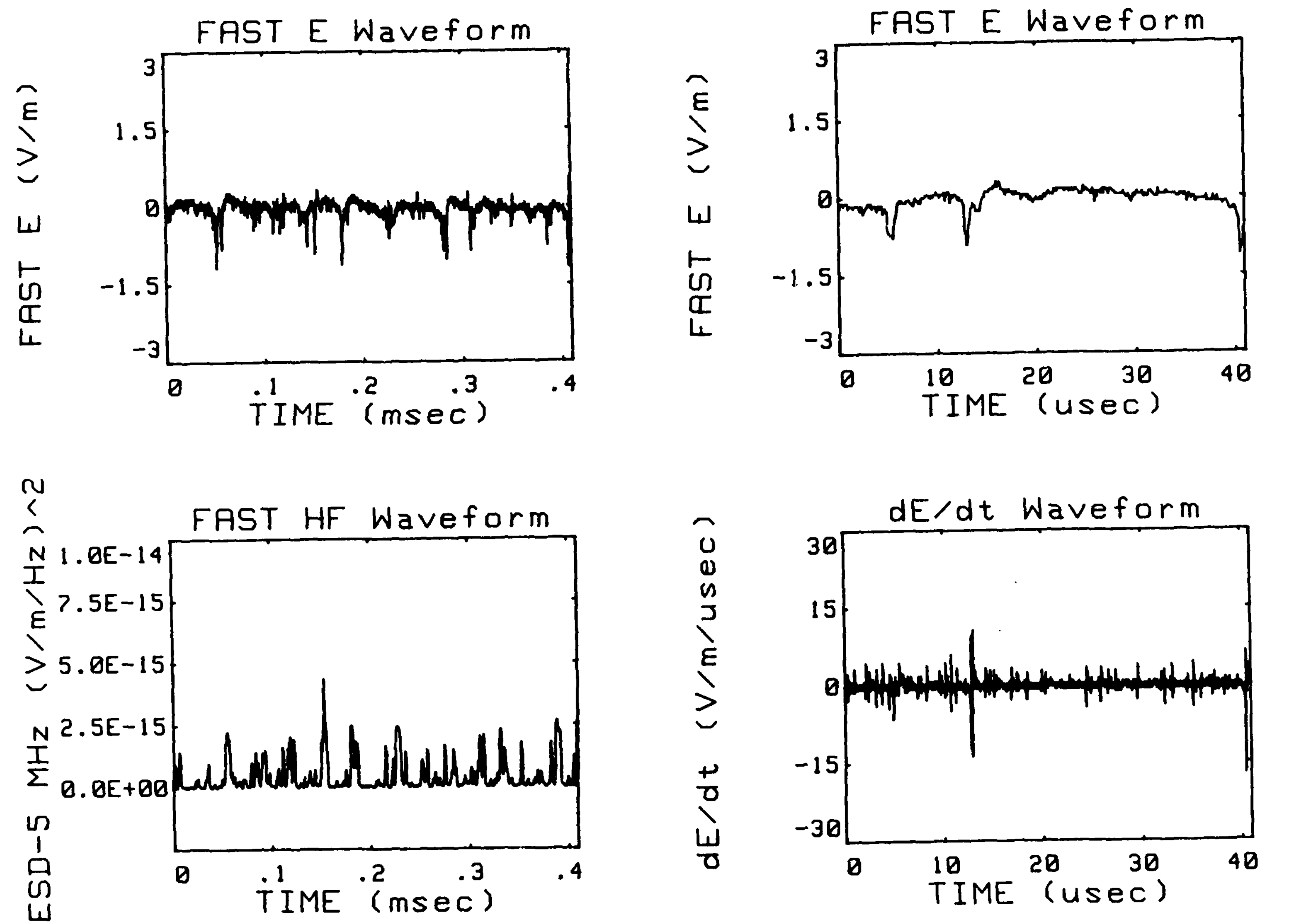
226181956.643 1985 1st RS (23.3 Km)



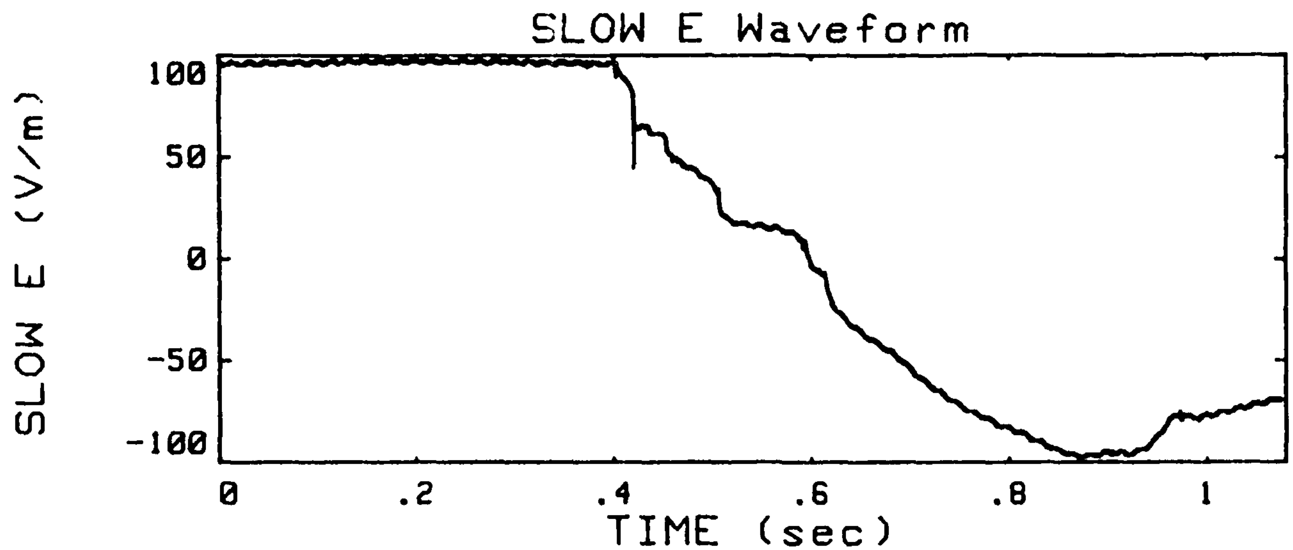
18:19:55.988 14 Aug 1985 (23.3 Km)

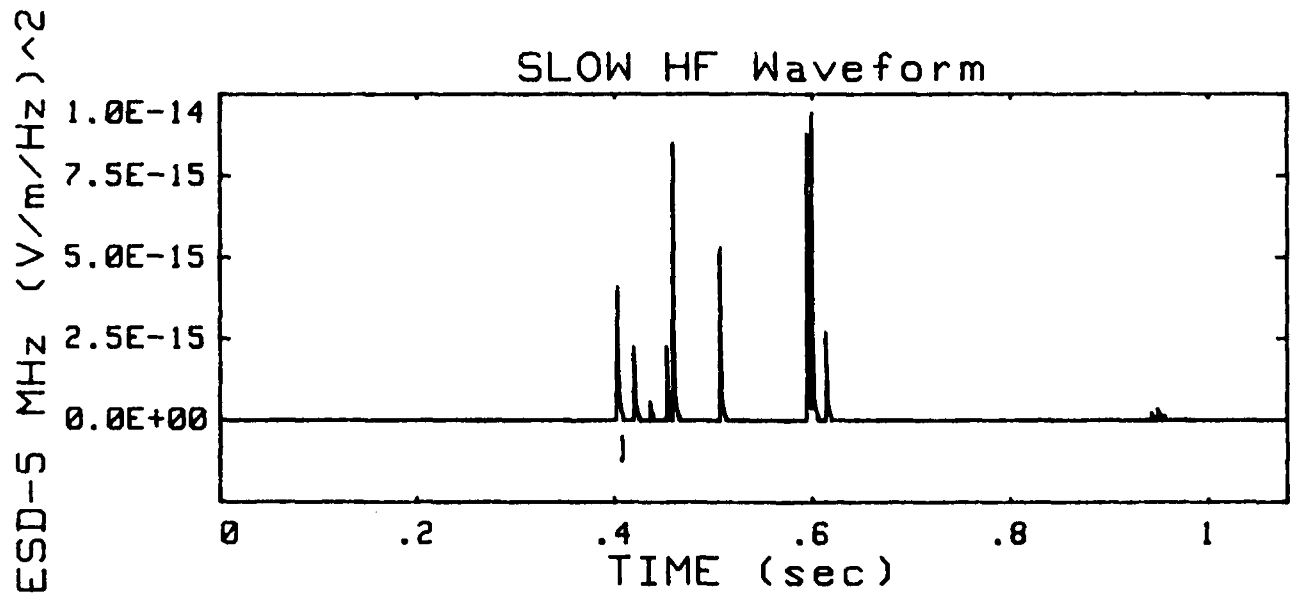


226182046.185 1985 Char Cloud Pulse (30.4 Km)

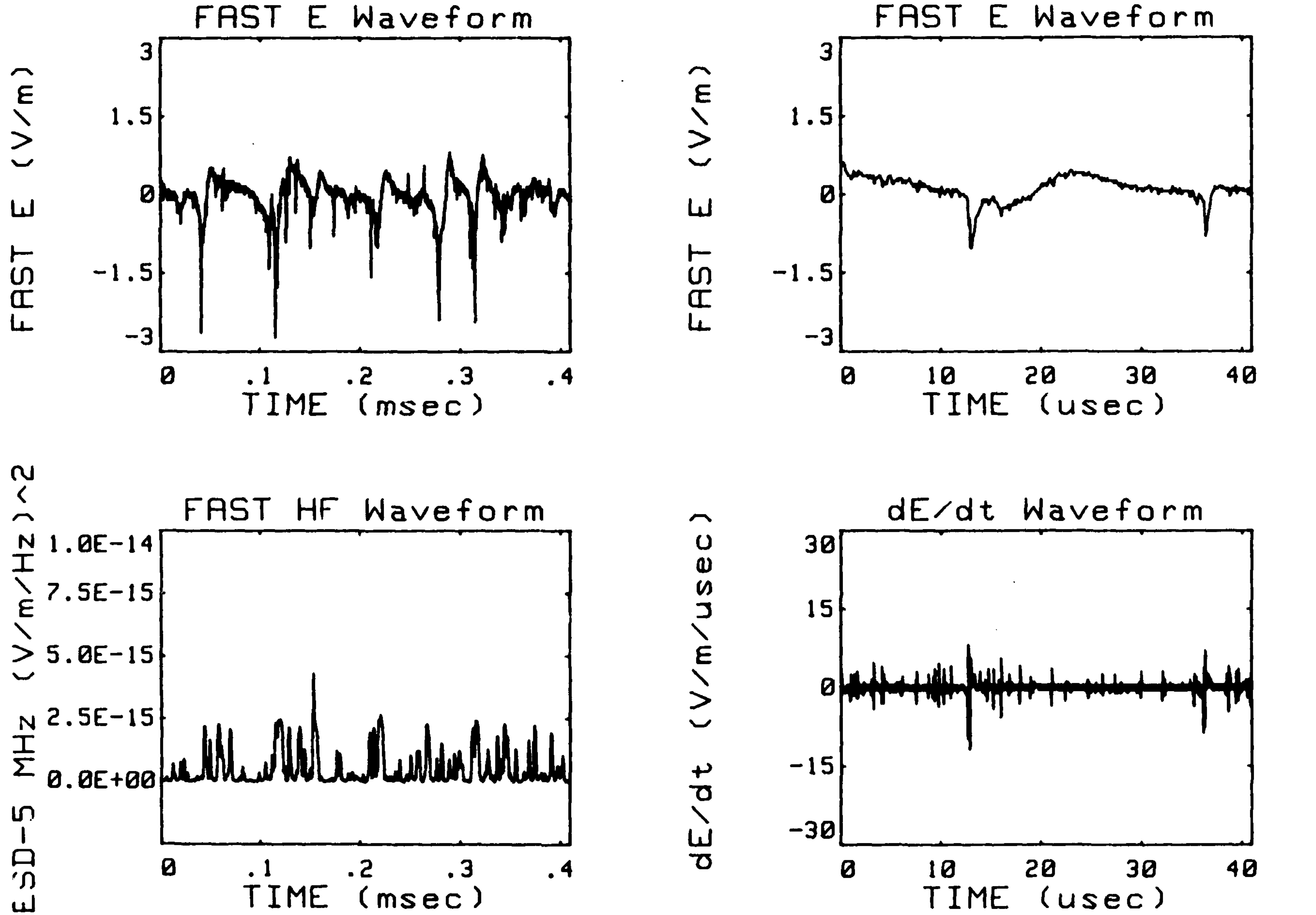


18:20:45.790 14 Aug 1985 (30.4 Km)

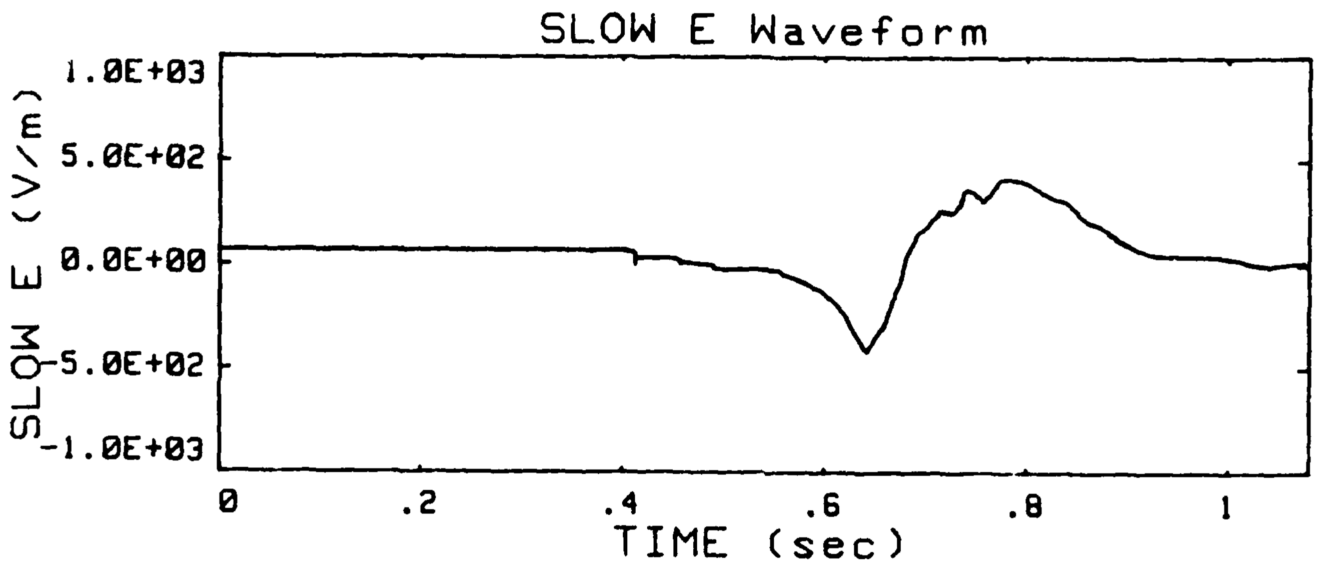


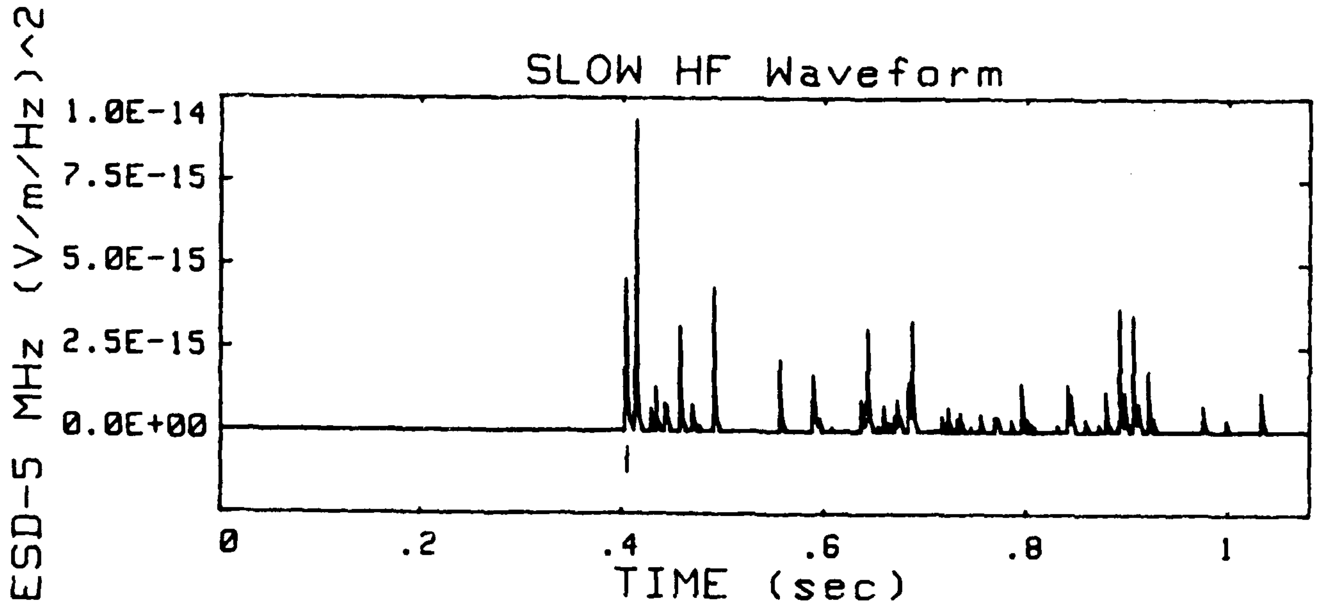


226182220.025   1985   Char Cloud Pulse   (30.1 Km)

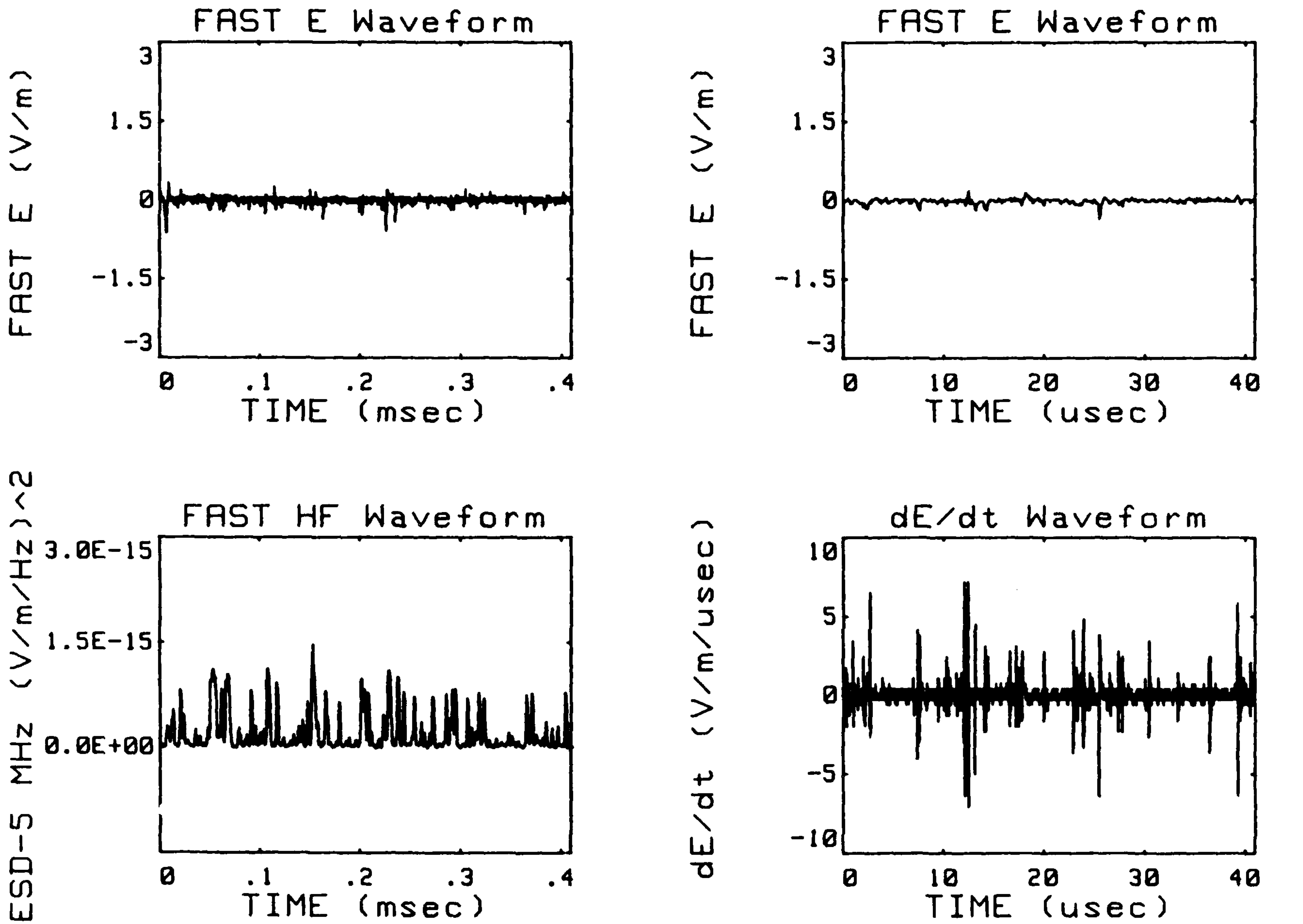


18:22:19.633 14 Aug 1985 (30.1 Km)

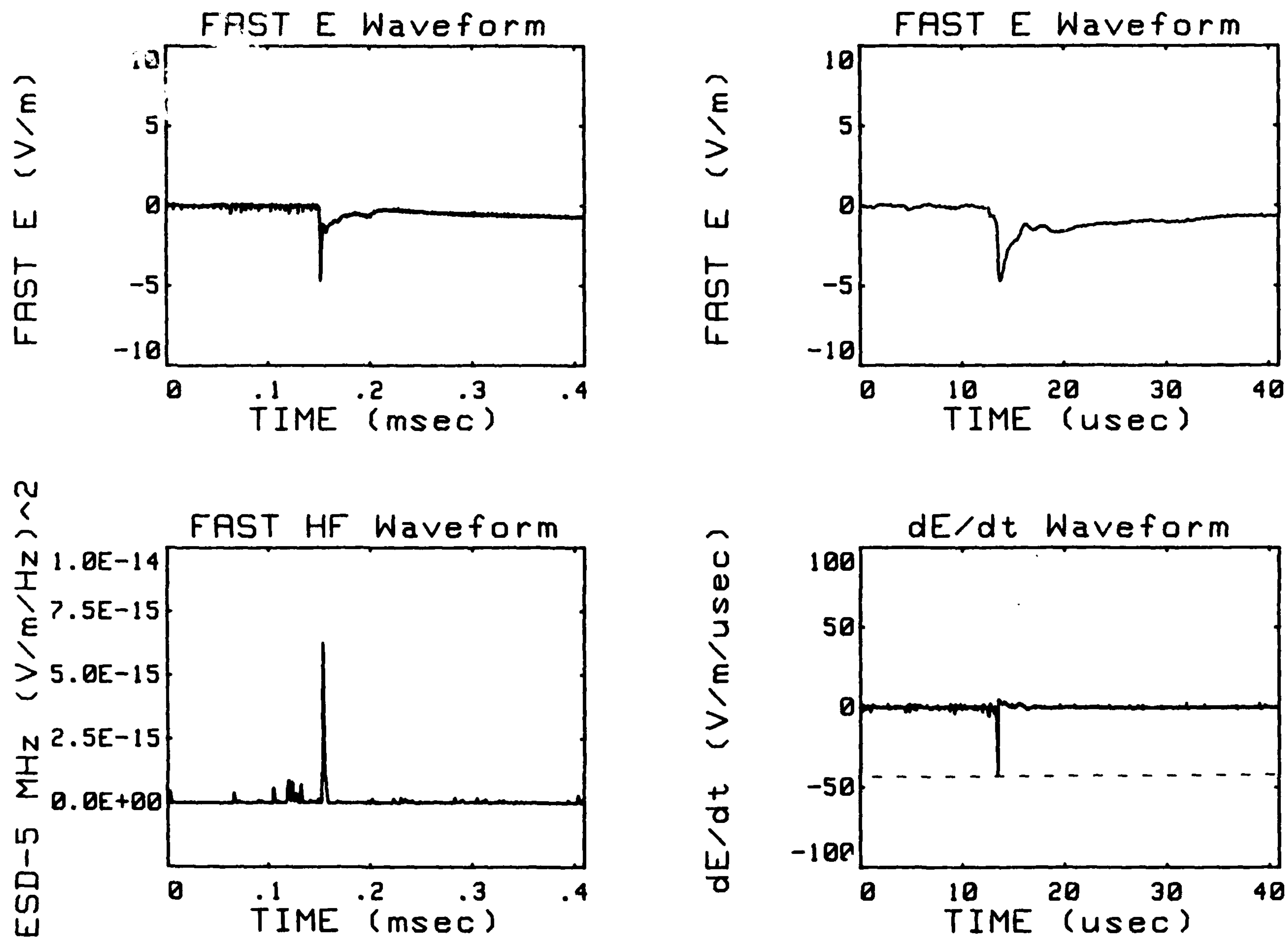




226182320.064 1985 Unknown Cloud (20.0 Km)

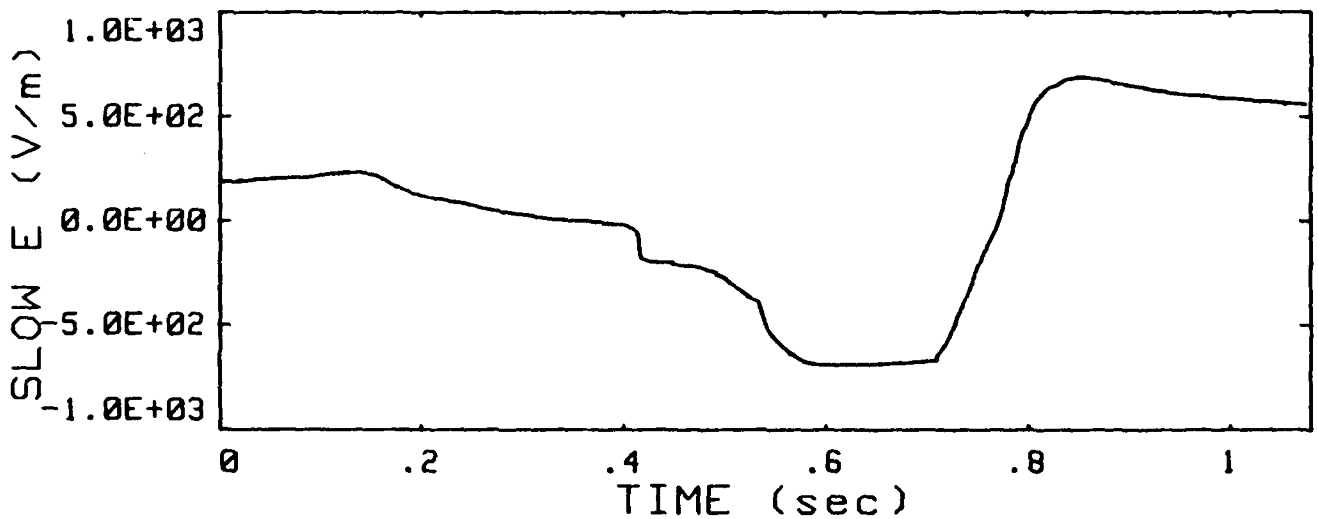


226182320.196 1985 DS Subs RS (20.0 Km)

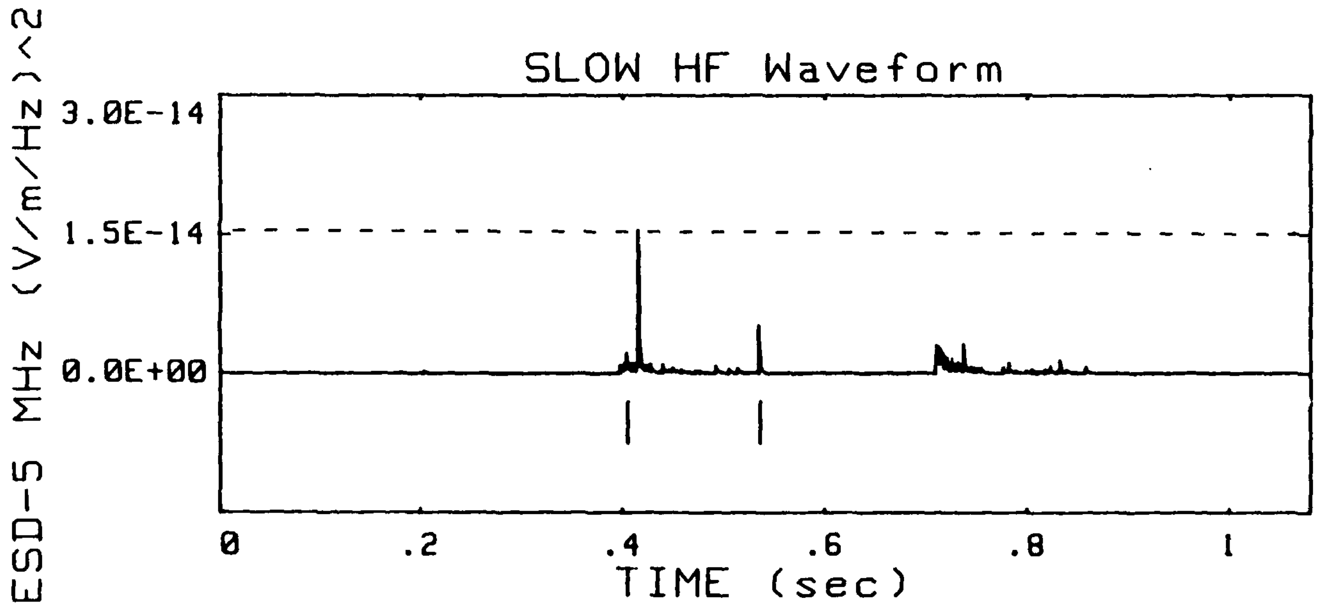


18:23:19.672 14 Aug 1985 (20.0 Km)

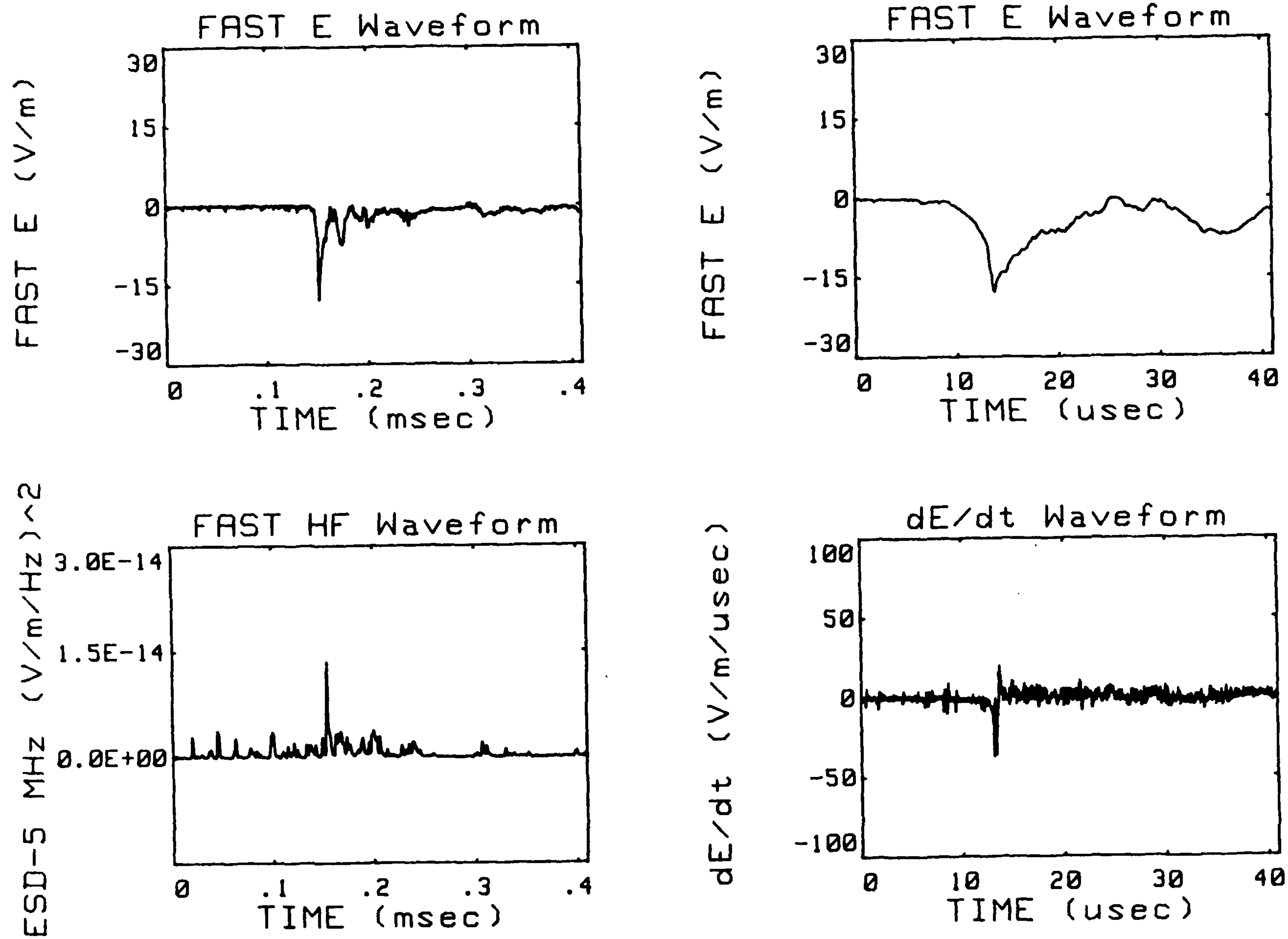
SLOW E Waveform

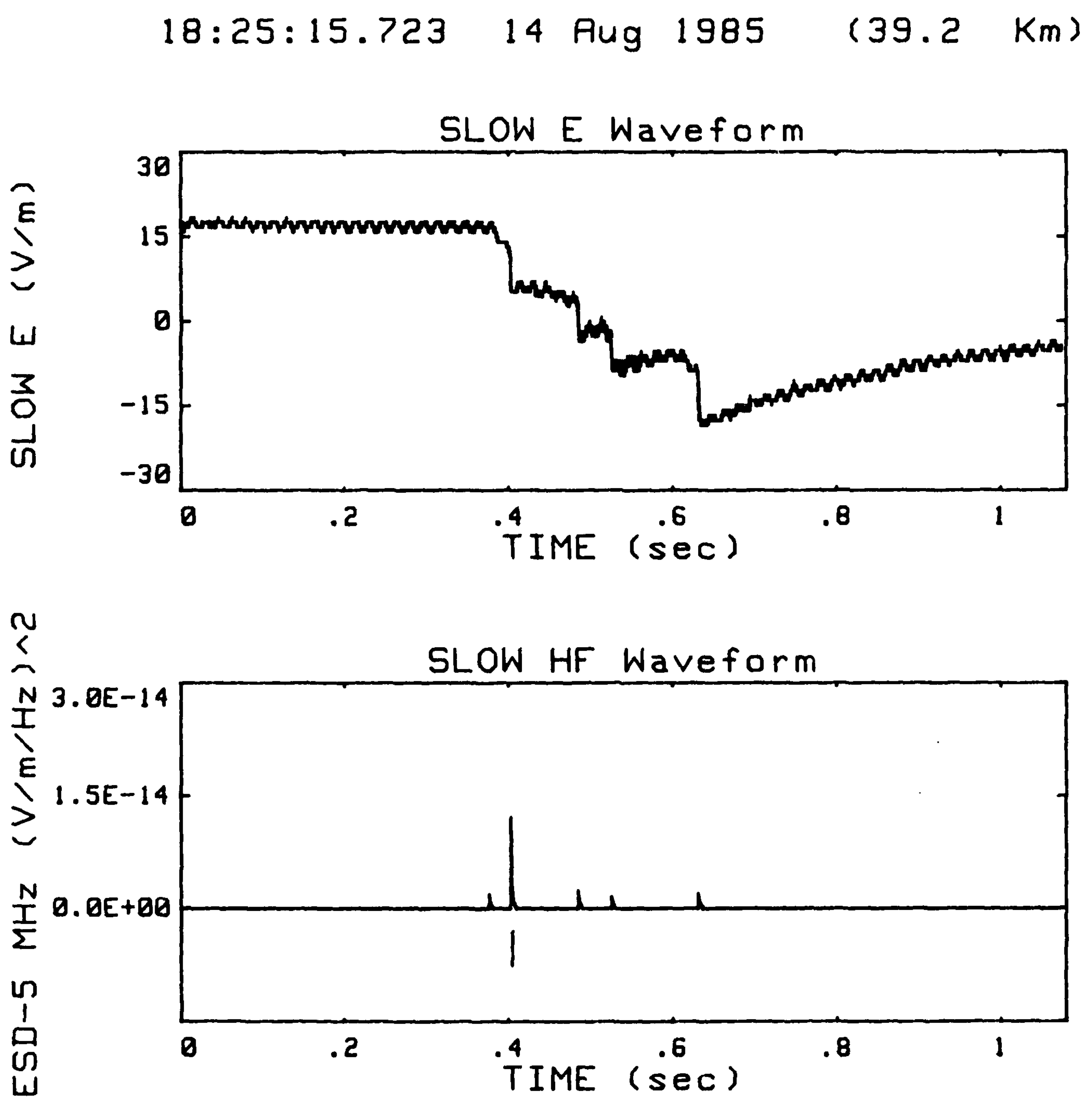


SLOW HF Waveform

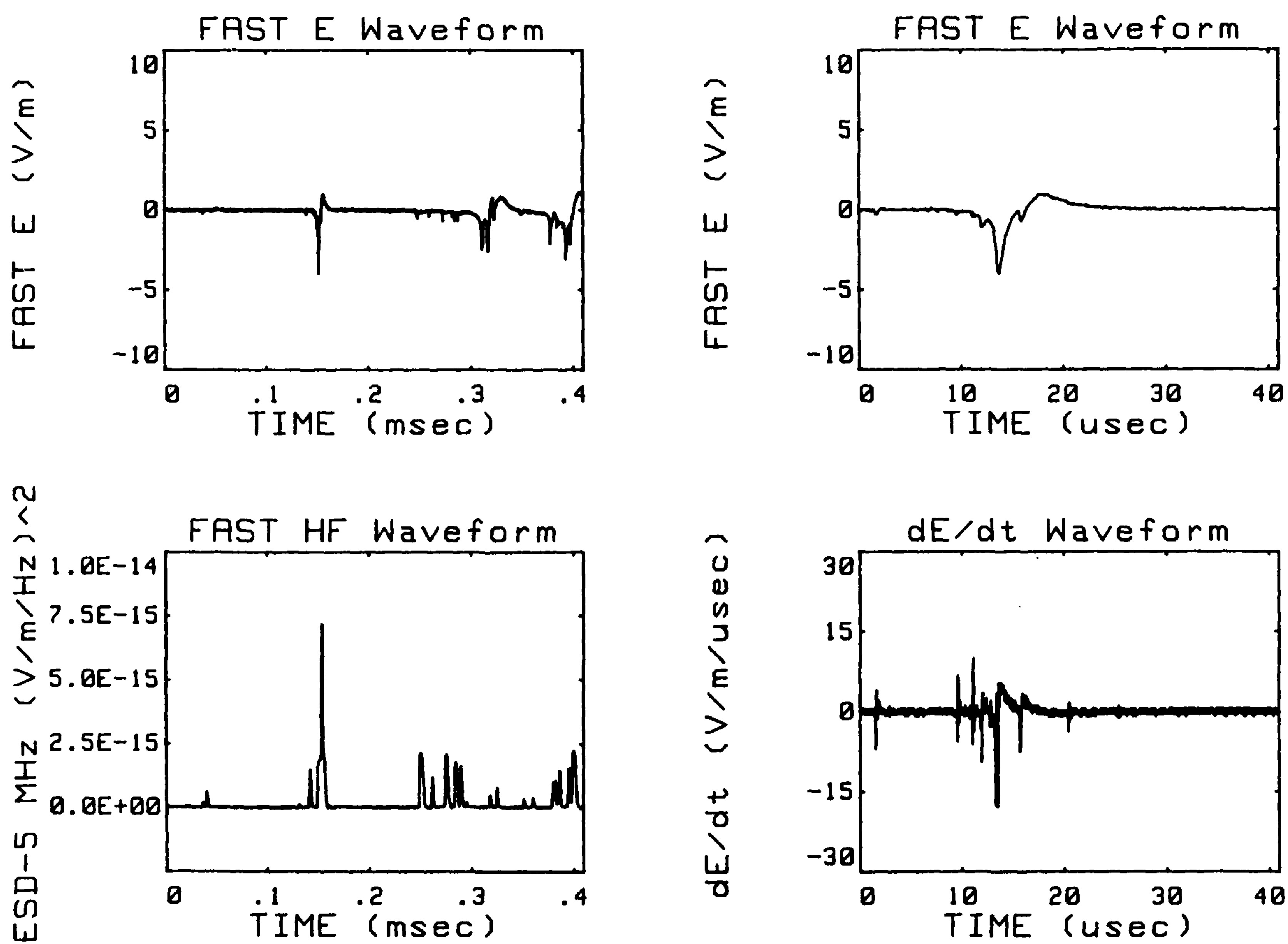


226182516.115 1985 1st RS (39.2 Km)

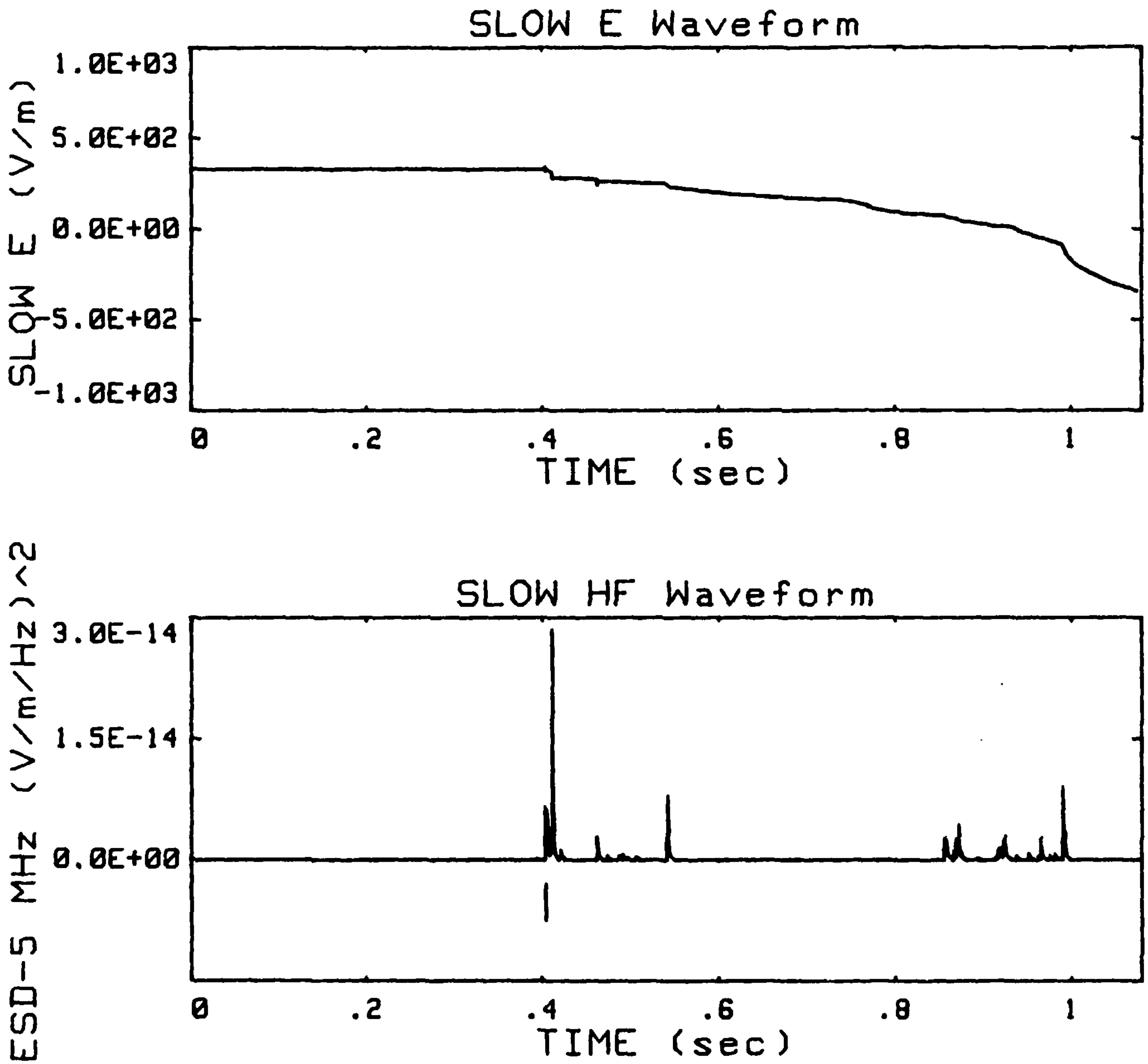



18:25:15.723 14 Aug 1985 (39.2 Km)
SLOW E Waveform
SLOW E (V/m)
30
15
0
-15
-30
0
.2
.4
.6
.8
1
TIME (sec)
SLOW HF Waveform
ESD-5 MHz (V/m/Hz)^2
3.0E-14
1.5E-14
0.0E+00
0
.2
.4
.6
.8
1
TIME (sec)

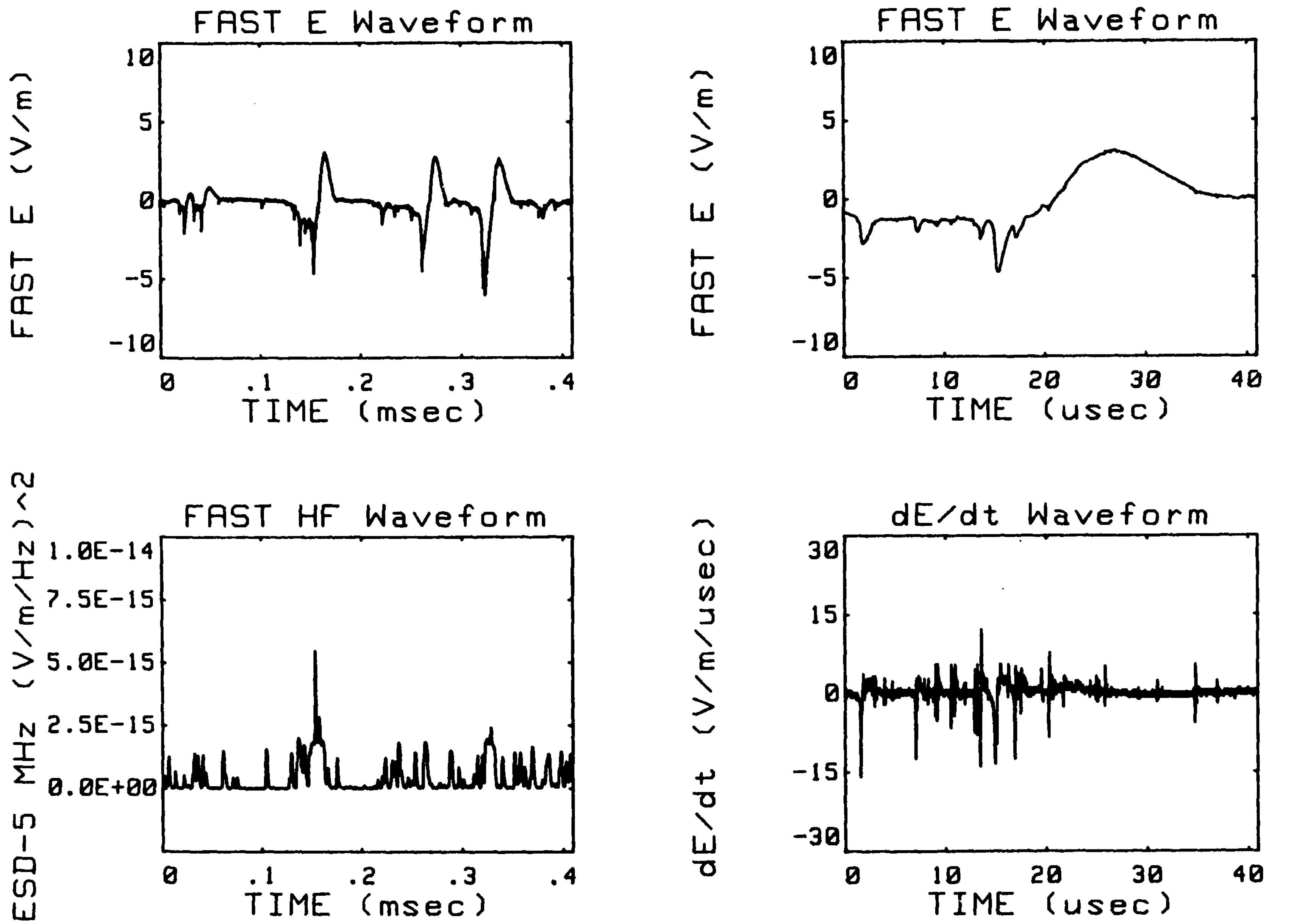
226182533.895 1985 Char Cloud Pulse (27.8 Km)



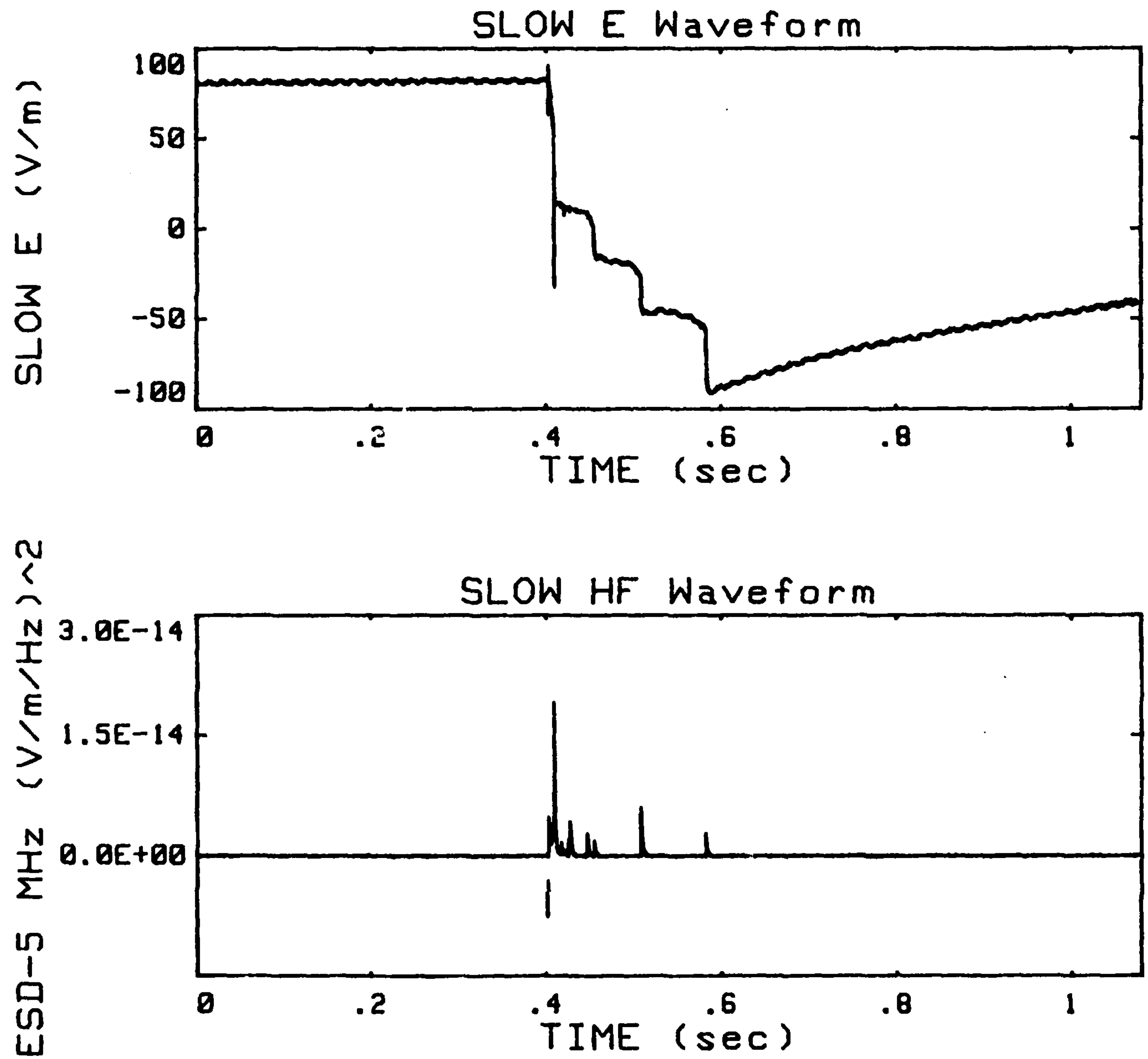
18:25:33.504 14 Aug 1985 (27.8 Km)



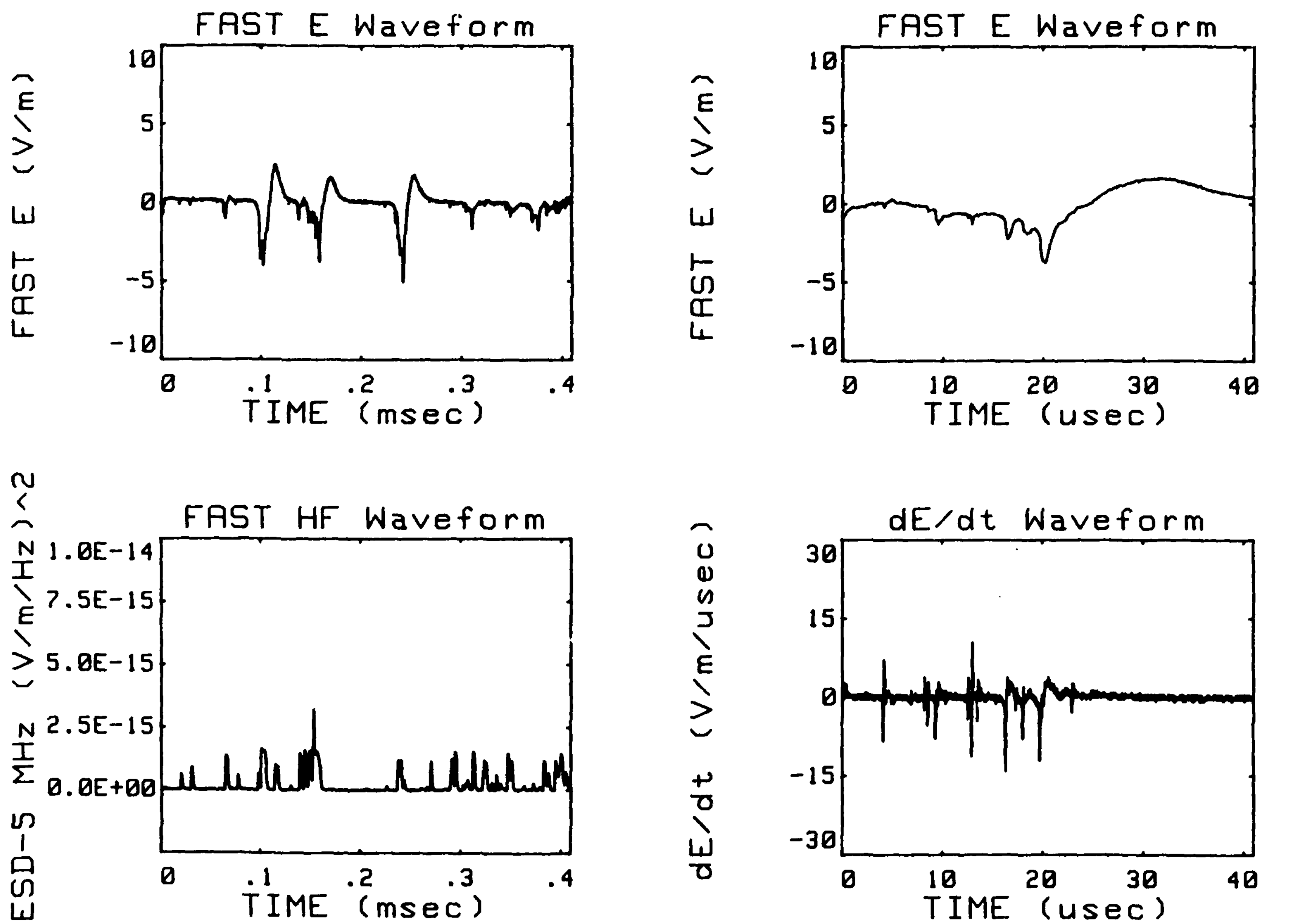
226182703.140 1985 Char Cloud Pulse (26.4 Km)



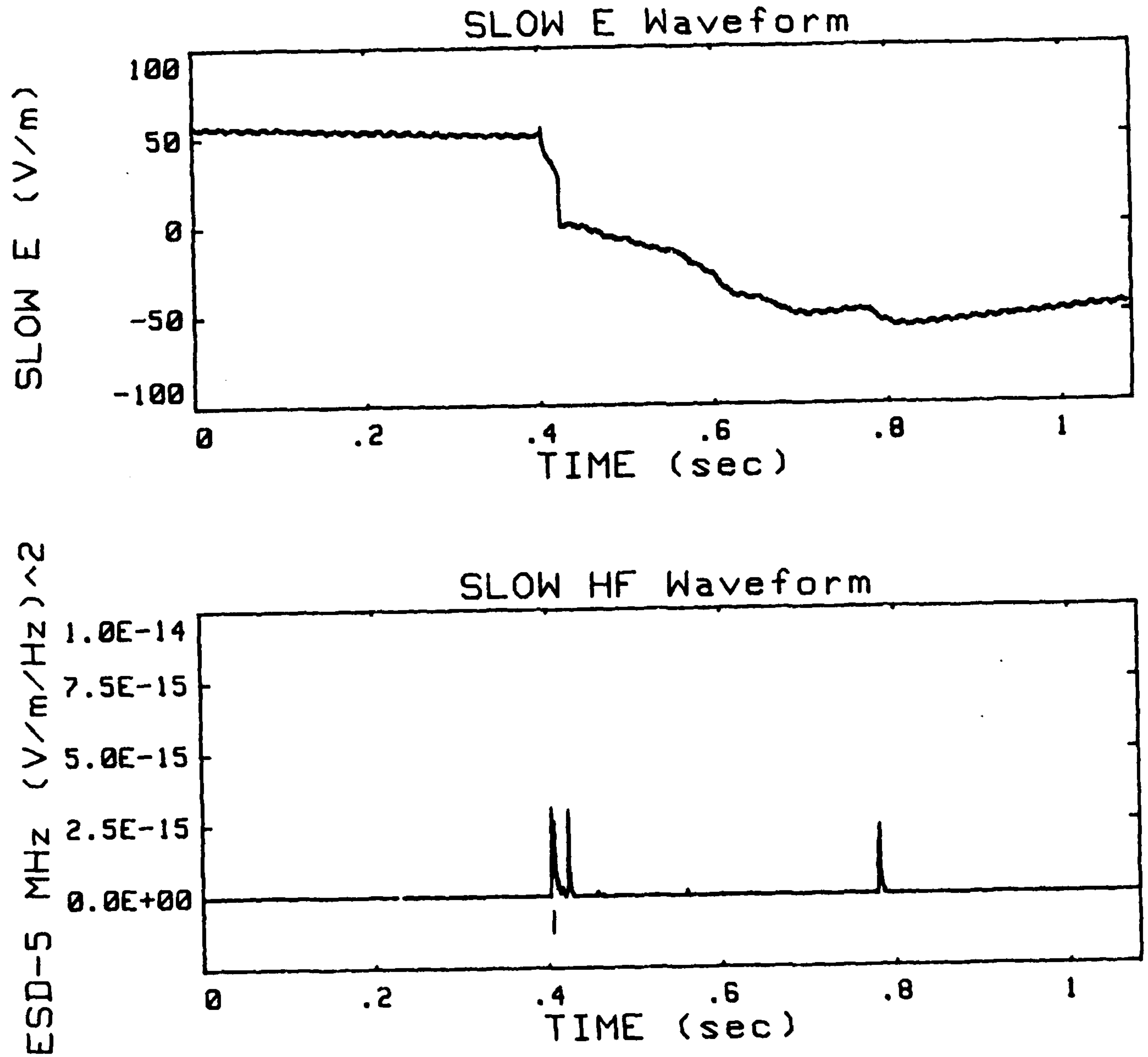
18:27:02.751 14 Aug 1985 (26.4 Km)



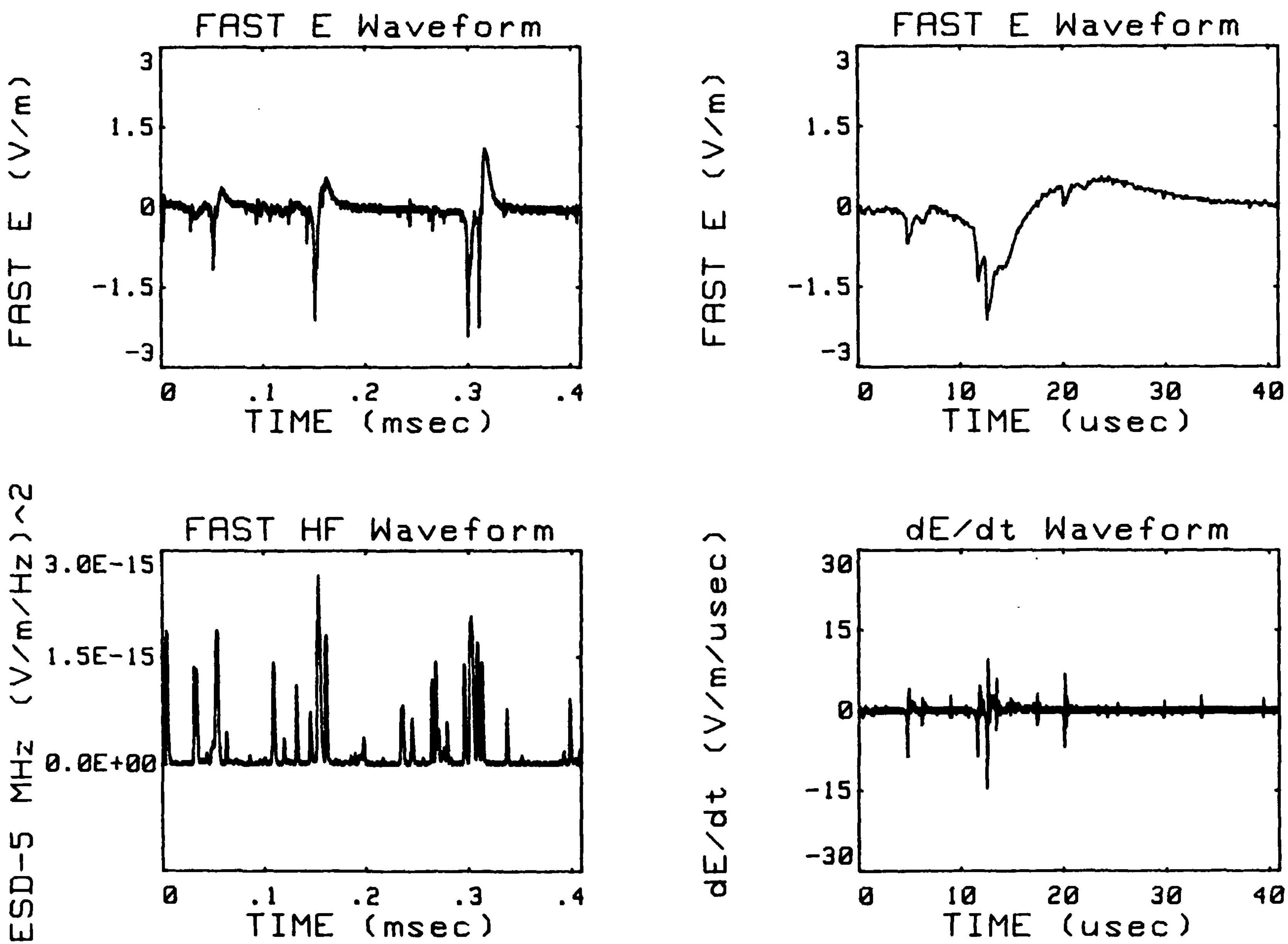
226183158.540 1985 Char Cloud Pulse (24.5 Km)



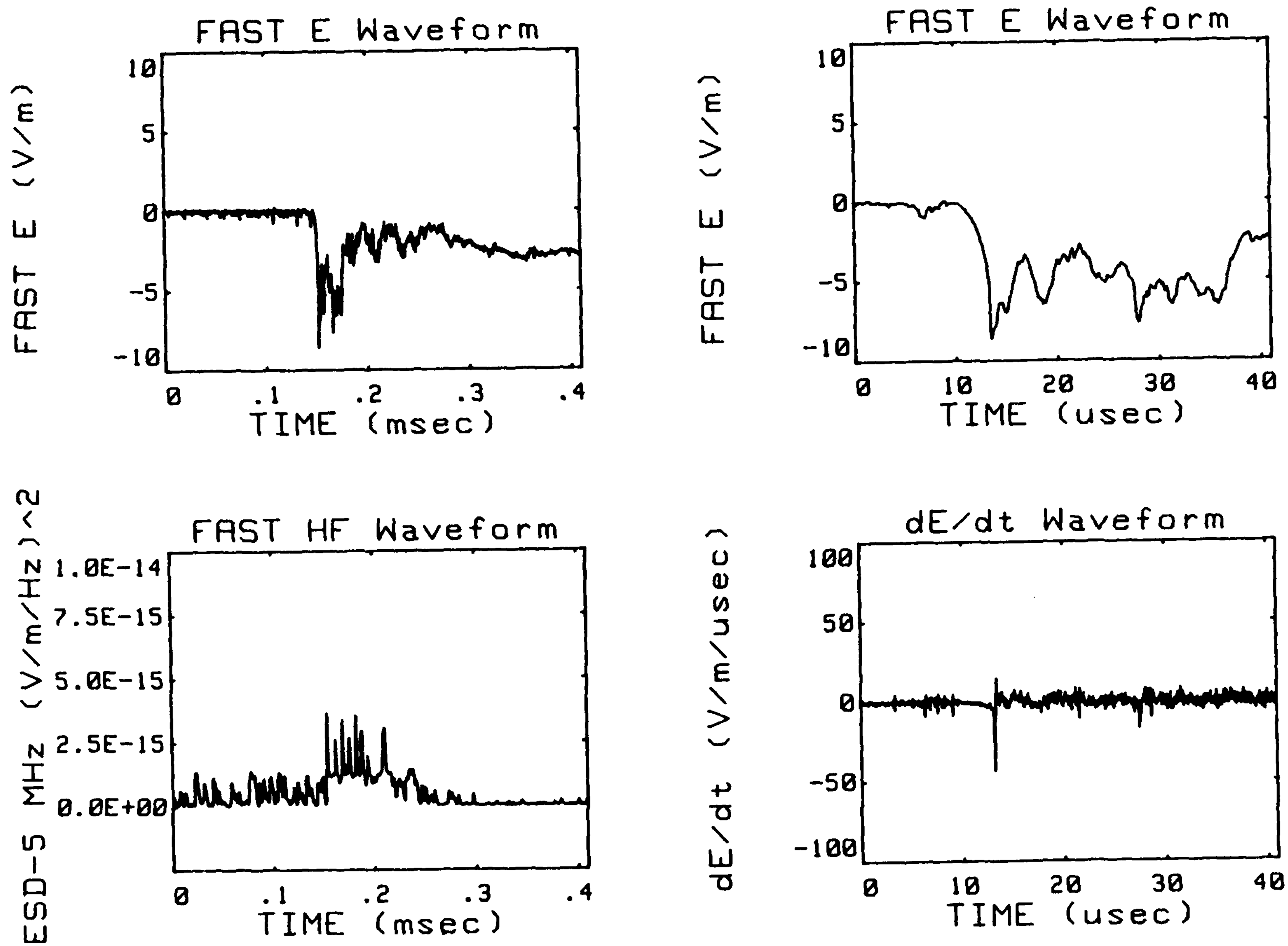
18:31:58.148 14 Aug 1985 (24.5 Km)



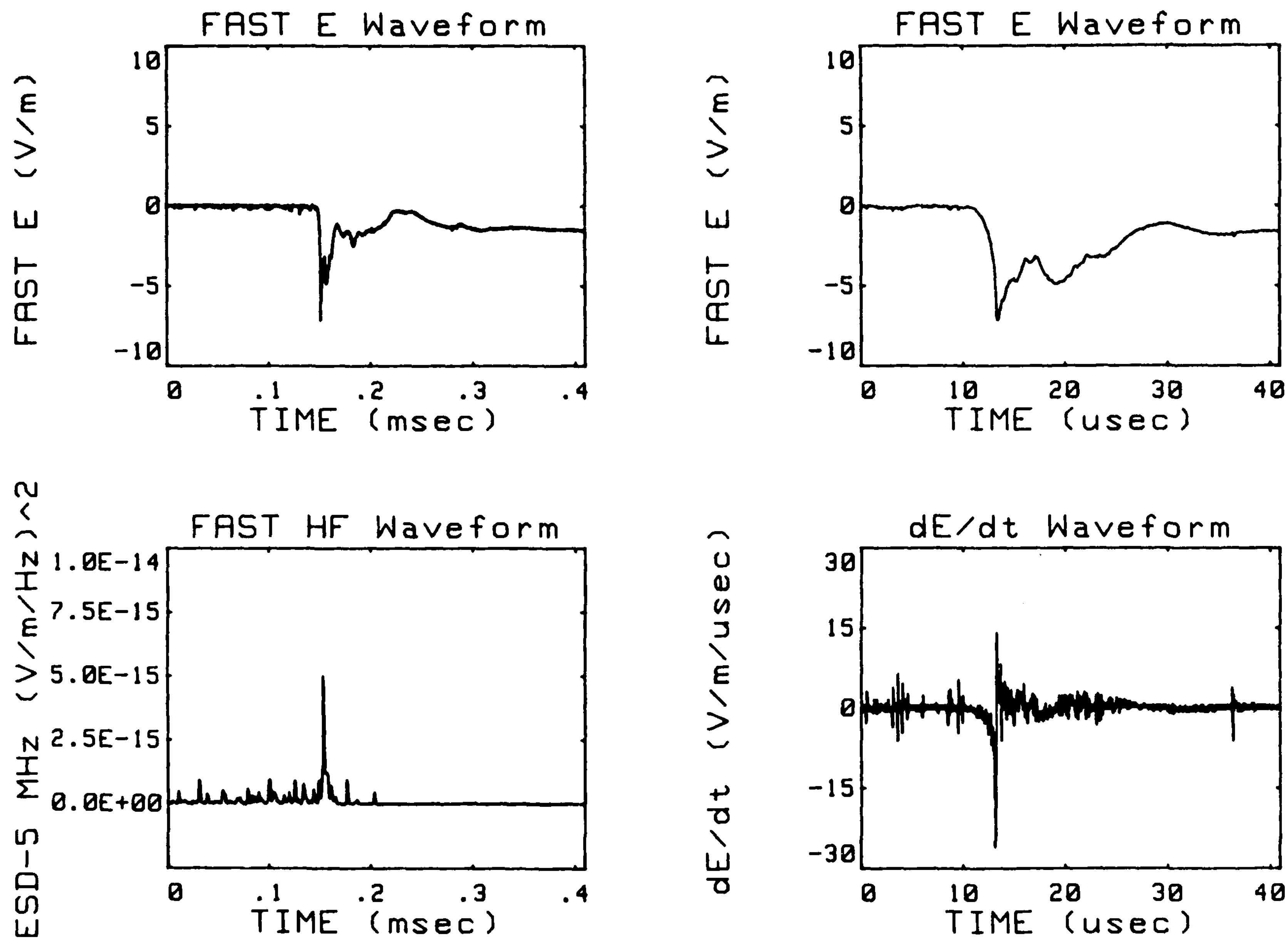
226183451.702 1985 Char Cloud Pulse (26.7 Km)

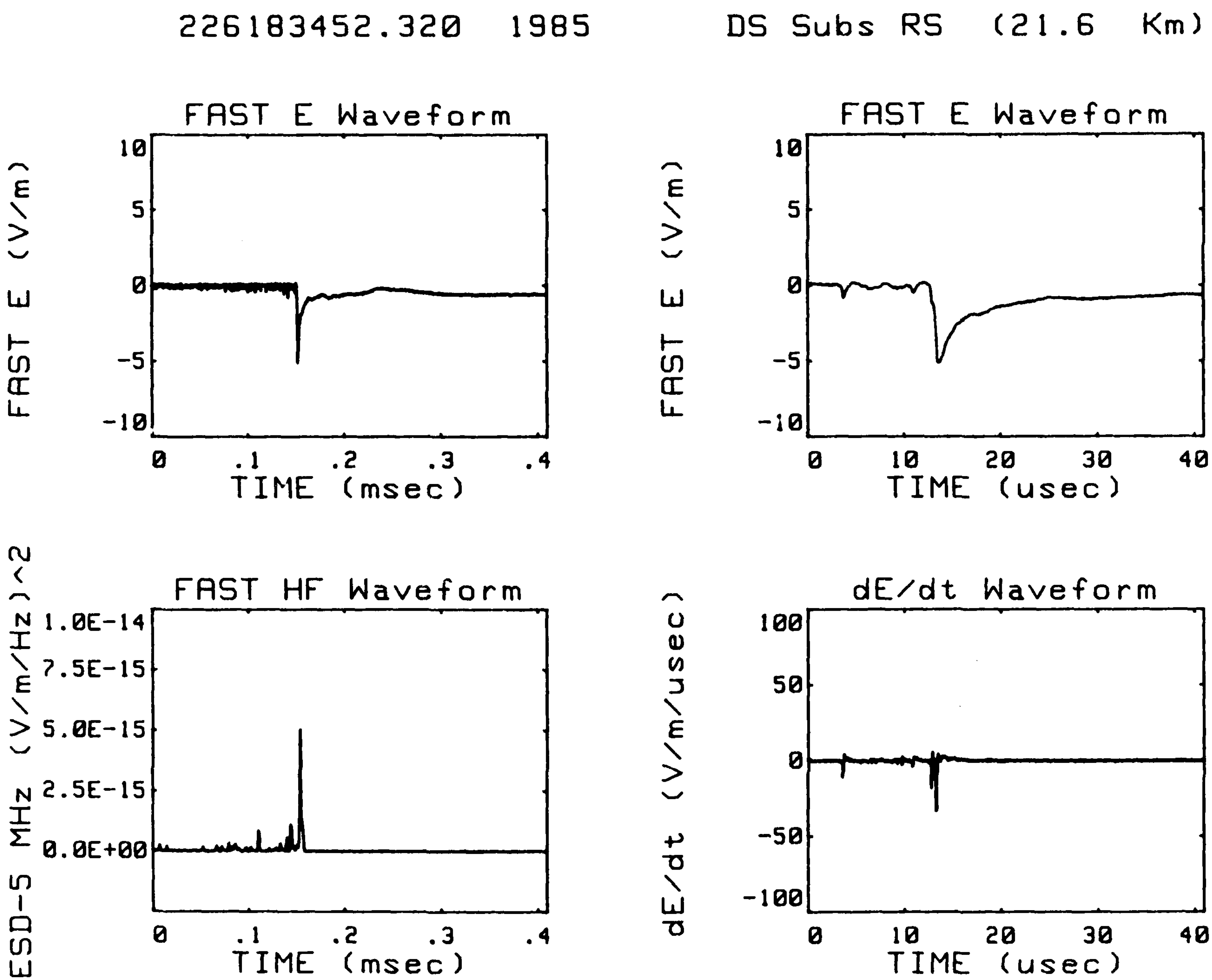


226183452.042 1985 1st RS (21.6 Km)

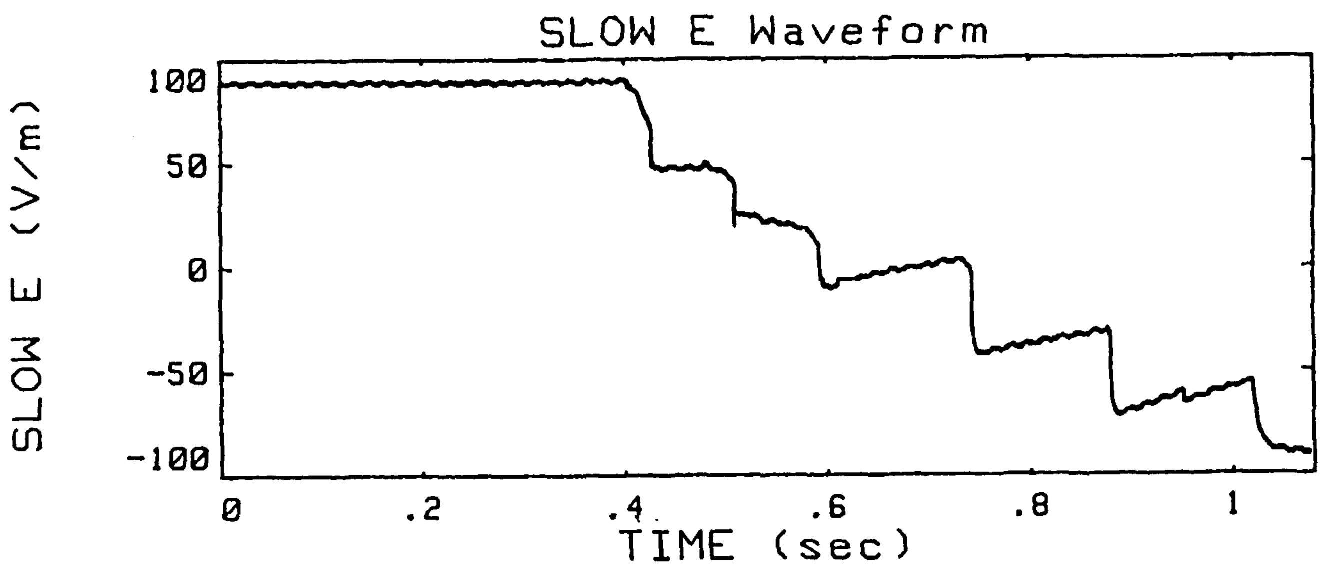


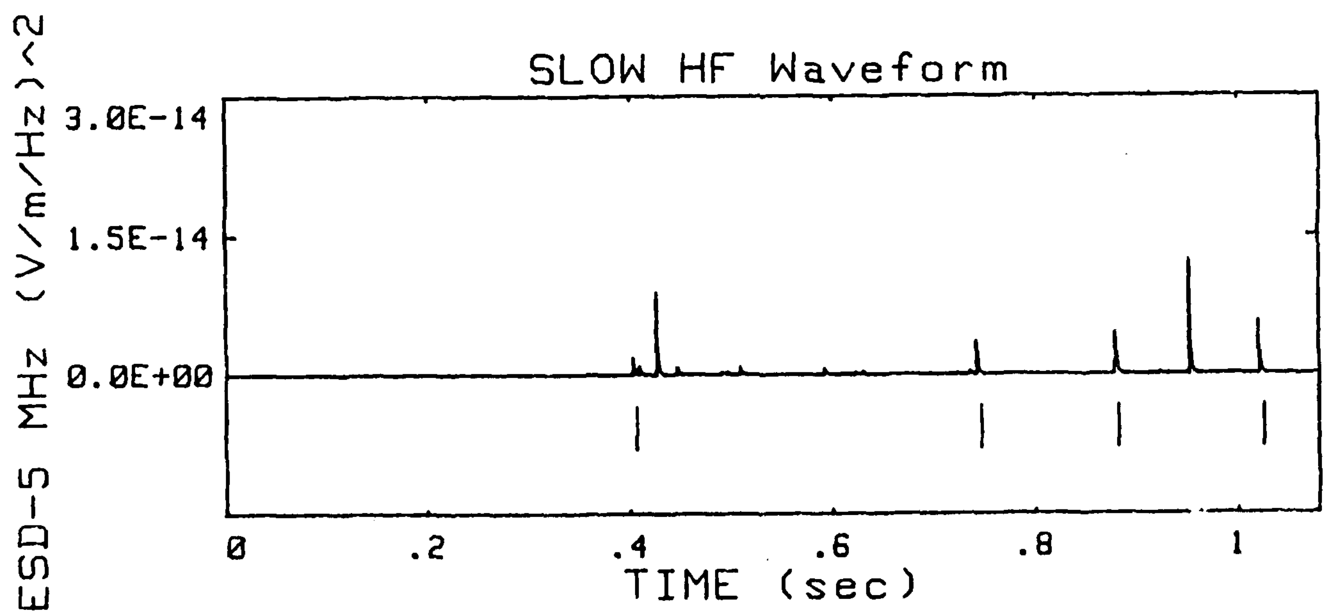
226183452.177 1985 DS Subs RS (21.6 Km)



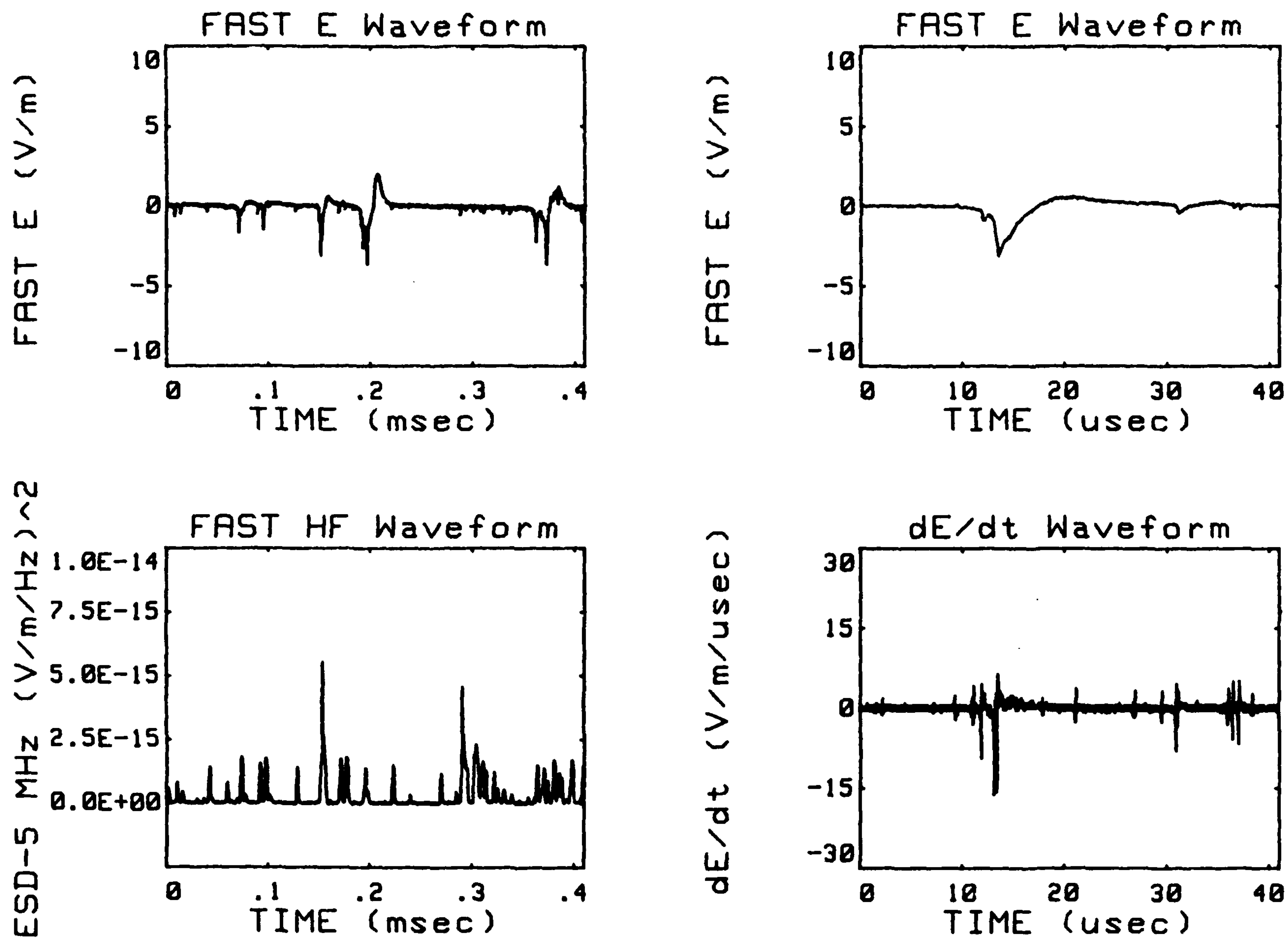

226183452.320 1985
DS Subs RS (21.6 Km)
FAST E Waveform
FAST E (V/m)
10
5
0
-5
-10
0
.1
.2
.3
.4
TIME (msec)
FAST E Waveform
FAST E (V/m)
10
5
0
-5
-10
0
10
20
30
40
TIME (usec)
FAST HF Waveform
ESD-5 MHz (V/m/Hz)^2
1.0E-14
7.5E-15
5.0E-15
2.5E-15
0.0E+00
0
.1
.2
.3
.4
TIME (msec)
dE/dt Waveform
dE/dt (V/m/usec)
100
50
0
-50
-100
0
10
20
30
40
TIME (usec)

18:34:51.311 14 Aug 1985 (21.6 Km)

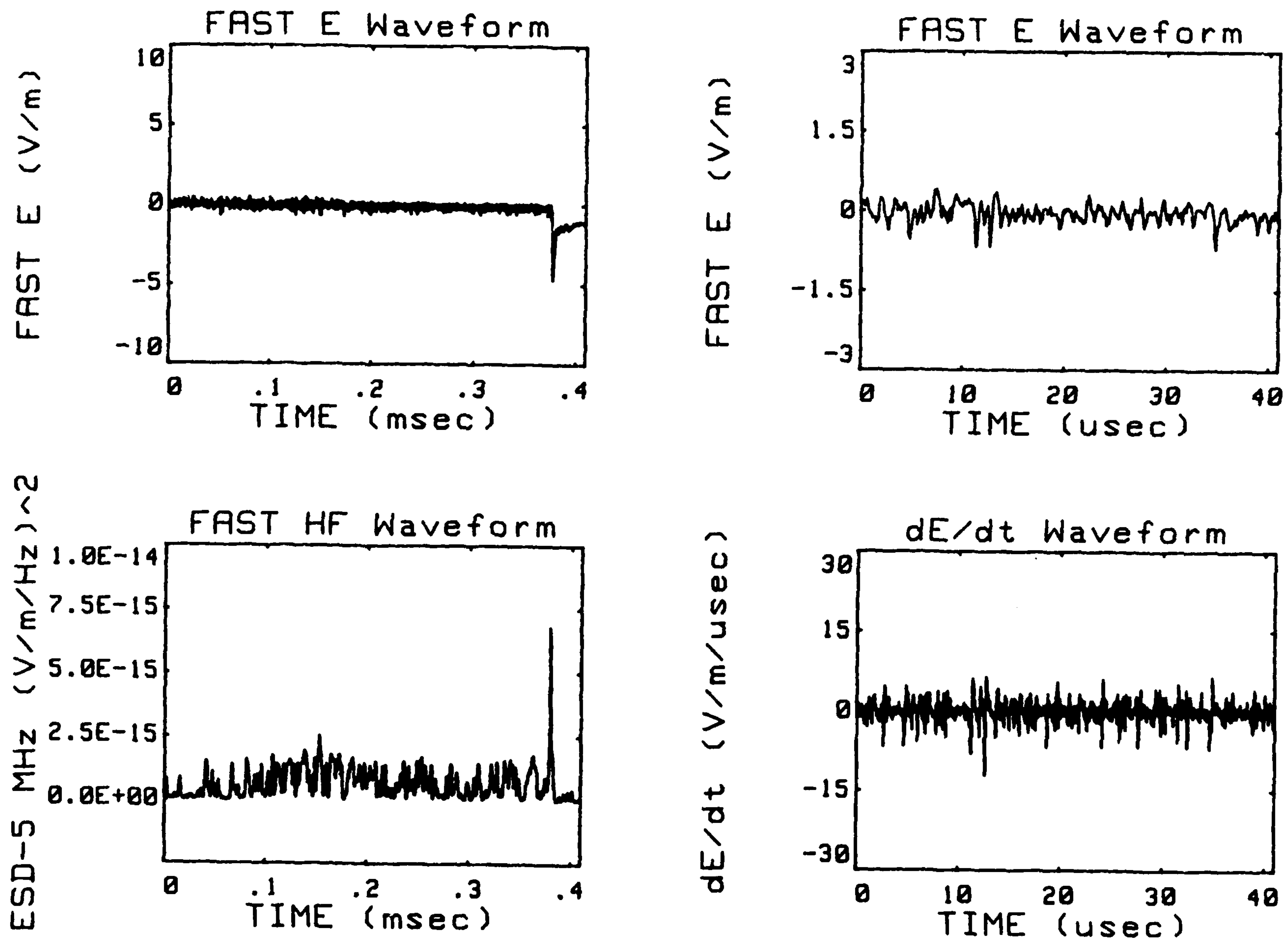




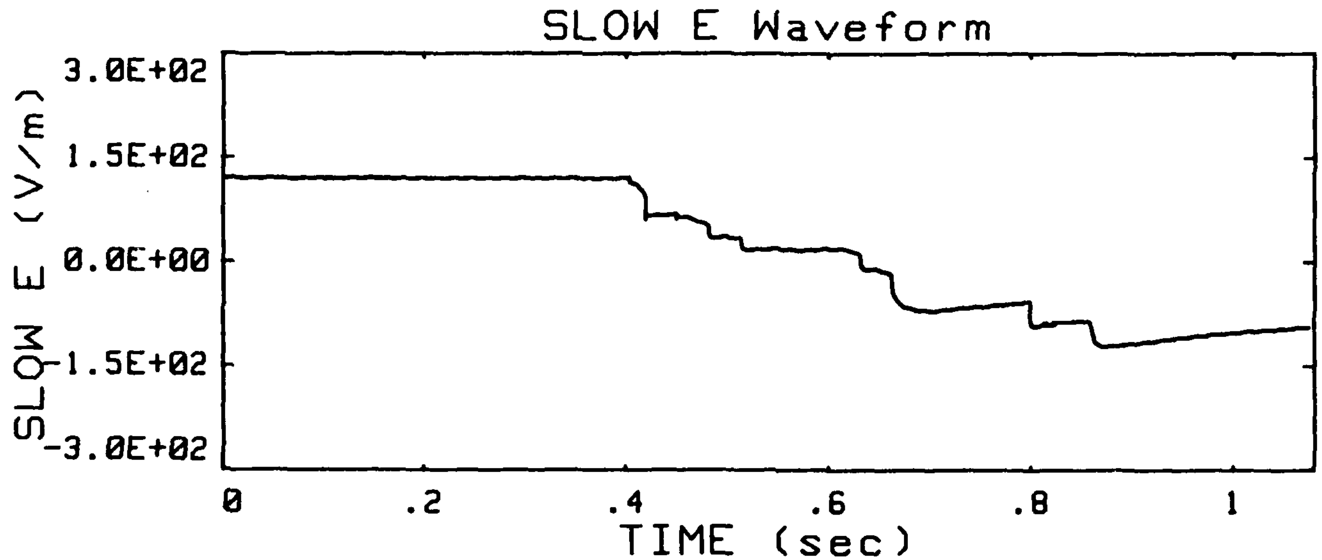
226183627.663 1985 Char Cloud Pulse (26.5 Km)

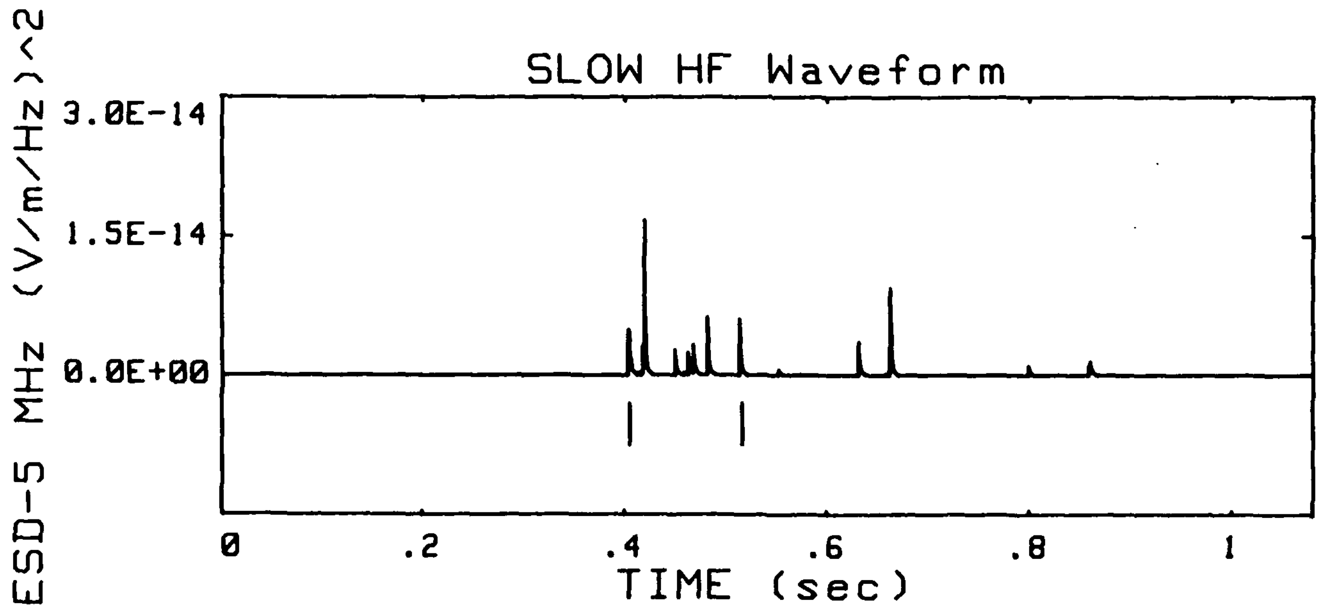


226183627.775 1985 DS Leader (26.5 Km)

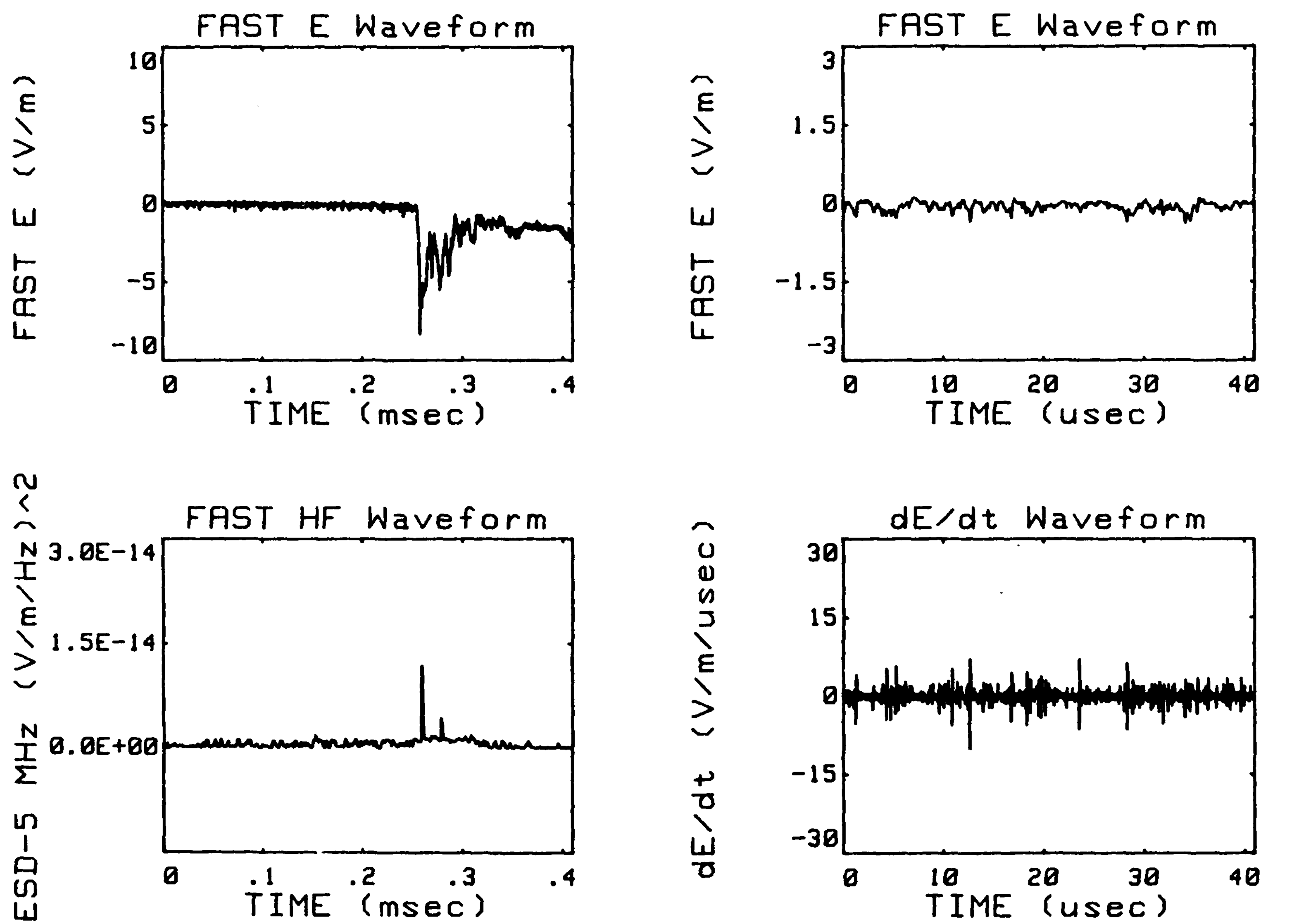


18:36:27.271 14 Aug 1985 (26.5 Km)

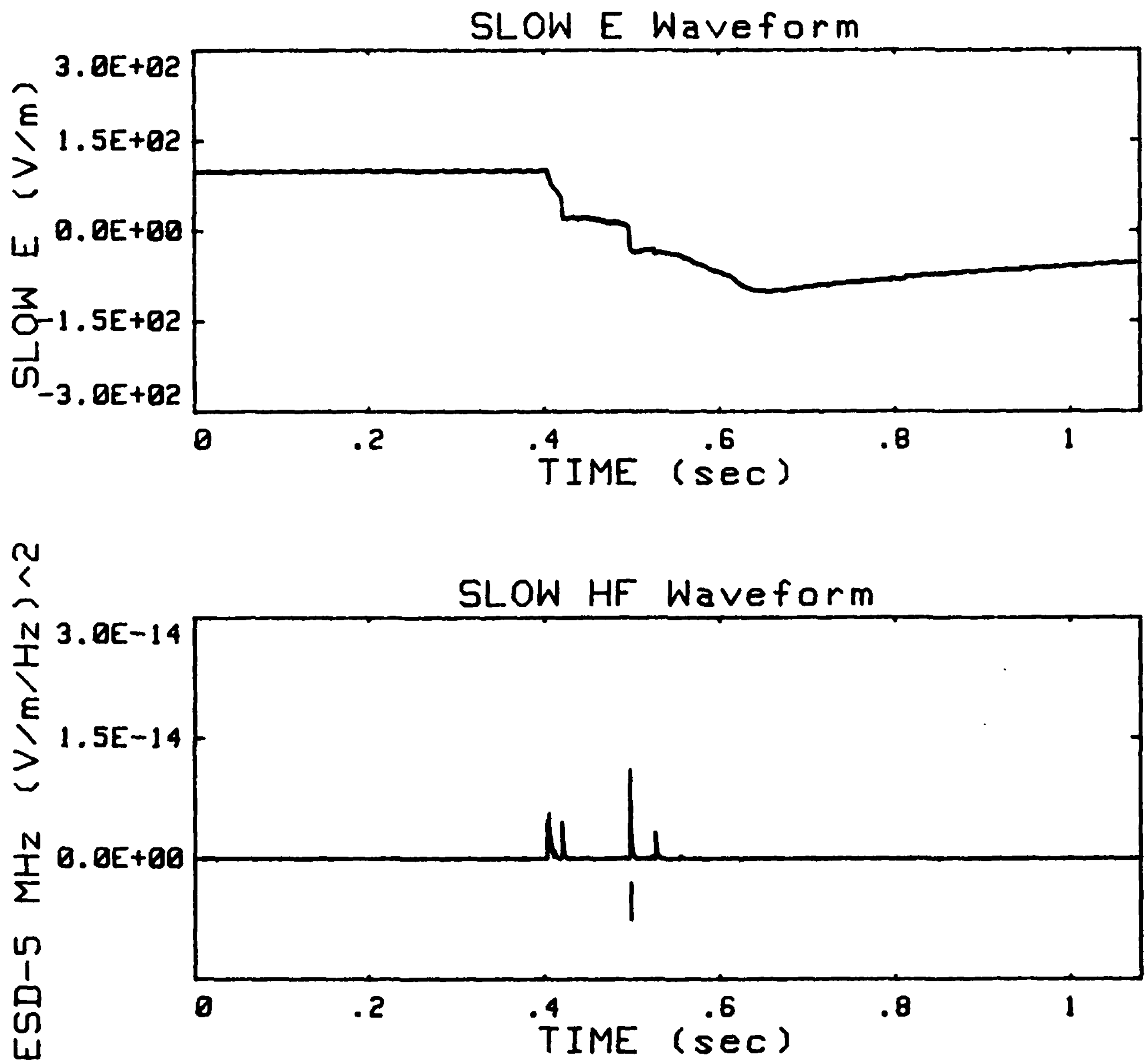




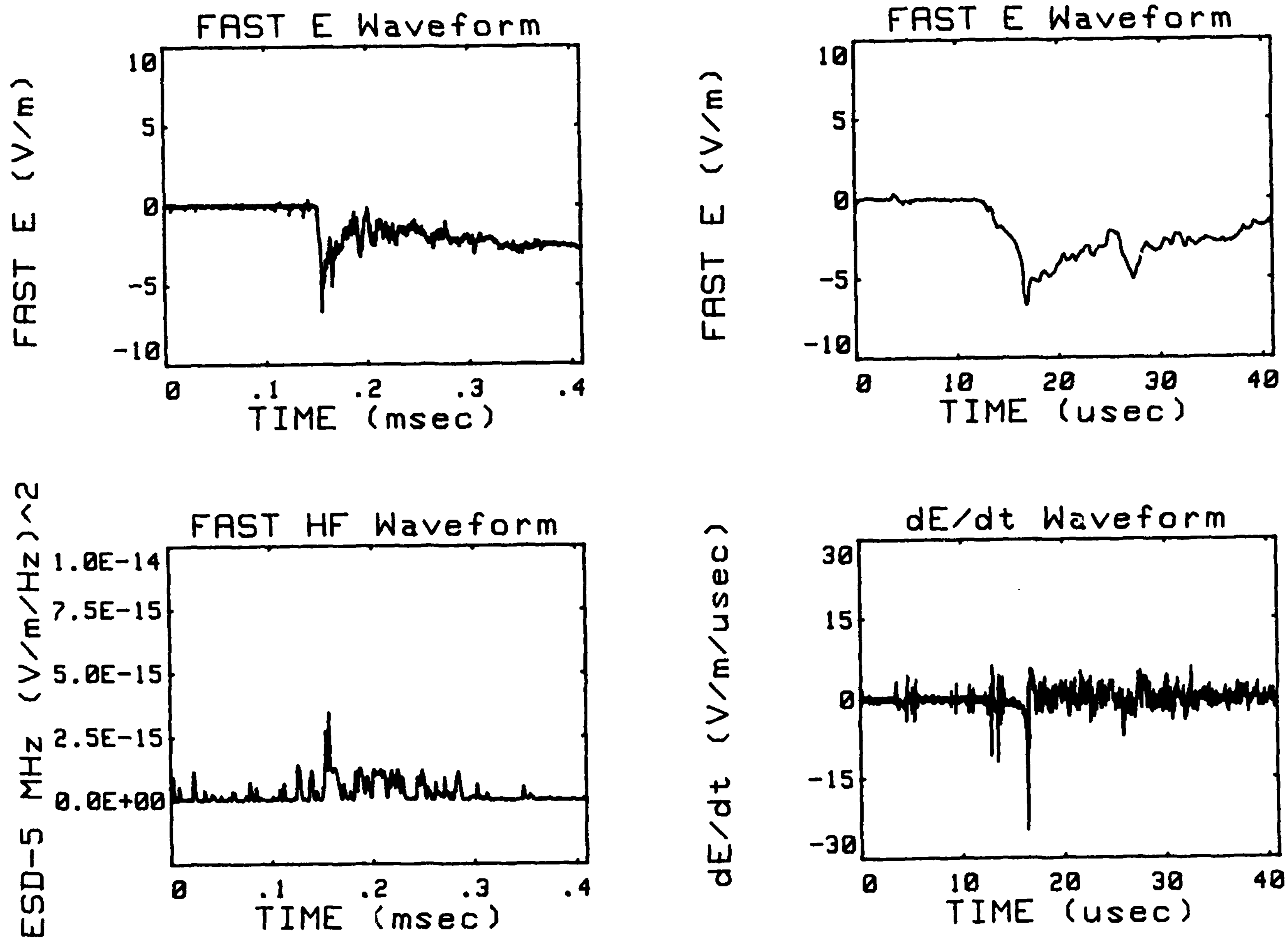
226183949.944 1985 Stepped Leader (22.0 Km)



18:39:49.458 14 Aug 1985 (22.0 Km)



226184055.066 1985 1st RS (21.7 Km)



18:40:54.541 14 Aug 1985 (21.7 Km)